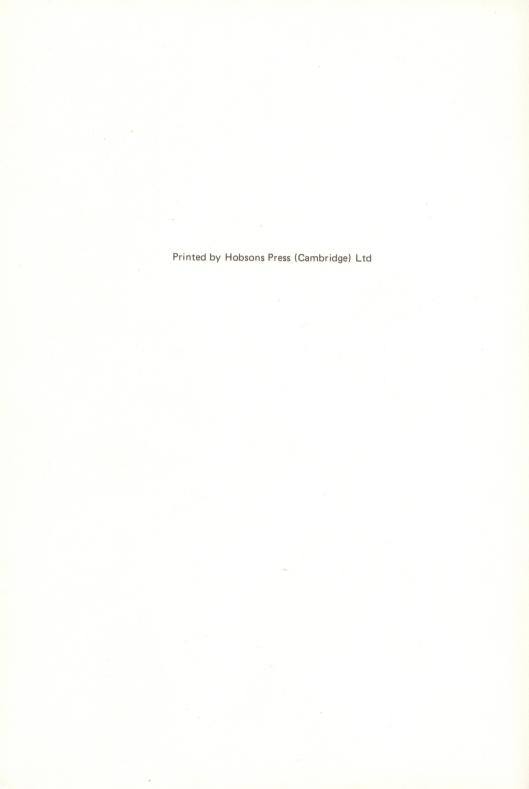
# 2

### **Mathematics**

Program Library

Algebra
Calculus
Geometry
Trigonometry
Number Theory
Transcendental Functions



### Mathematics

2

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#### How to use these programs

Each program is arranged as follows:

- On the left of the page, explanatory information and the 'execution sequence', the sequence of keystrokes necessary for running the program. Results displayed are printed in gold.
- 2. In the first column on the right hand side of the page, the sequence of keystrokes which make up the program.
- 3. In the second and third columns on the right hand side of the page, the program in check symbol and step number form (see section on checking the program).

#### Notes

1.	Where a key has more than one function, the relevant function is
	printed as the keystroke in the first column

e.g. the keystroke 8 may appear as 8, cos or arccos.



3. The symbol # refers to 3

4. The abbreviation gin is 'go if neg' and so refers to the key 1

#### **Entering the program**

To enter a program into the calculator:

1. Press 🔊 🙎 0 0 Display shows step programmed at 00 in check symbol form as described below.

2. Press ■ RUN No change in display.

3. Press the sequence of keys for the program as shown in the first column of the program page.

At each stage the step about to be overwritten is displayed.

When the machine is first switched on every step is zero.

Normal number display is resumed.

5. Press 💵 2 0 0 The step programmed at 00 will be displayed.

#### Checking the program

Each of the programs in the library is shown in check symbol form in the second column on the right-hand side of the page.

Press C/CE repeatedly, and at each stage the check symbol will appear on the left of the display with the step number on the right. Ignore the four zeros in the display.

e.g. A.0000 03

check step symbol number

After stepping through the program, press

Finally, press C/CE and the program is ready for use.

#### Correcting the program

If the check symbol for a particular step number is not as indicated in the last two columns of the program page:

1. Press 🕶 2

followed by the step number if the appropriate step number is not already displayed.

2. Press AT RUN

Enter the correct keystroke. The display will then show the next step in the program. If this is also incorrect, enter the correct keystroke. At each stage, the step about to be overwritten will be displayed.

4. When correction has been completed, press C/CE. Any step which has not been overwritten will not be affected.

5. Press **AV 2** 0 0

go to

Note

To restore normal use of the calculator after entering or checking the program, press  $\boxed{\text{C}_{\text{/CE}}}$ 

#### Running the program

Press the sequence of keys as shown in the program library in the execution sequence. Results displayed are printed in gold.

# EXTENSION OF RANGE OF TRIGONOMETRIC FUNCTIONS

to 
$$-\pi < \theta < \pi$$

Sine of any angle:

$$\sin \theta = \frac{2t}{1+t^2}$$
 where  $t = \tan \frac{\theta}{2}$ 

Execution:

 $\theta$  / RUN /  $\sin \theta$ 

For  $\theta$  in degrees, insert /  $\blacktriangledown$  / D $\rightarrow$ R / at start of program.

•	G	00
#	3	01
2	2	02
ese br	_	03
tan	9	04
u÷i e	G	05
(	6	06
X		07
+	Ε	80
#	3	09
1	1	10
0 2838	. 7V	11
)	6	12
+	Ε	13
		14
stop	0	15
	Α	16
goto	2	17
0	0	18
0	0	19
		20
	5893	21
the co		22
n the p		23
		24
	· Appen	25
081100	10111	26
		27
201	680	28
isola.ca		29
	sto	30
ngams	903	31
may is		32
ord arti	gari	33
den Des	erit	34
seque	oit	35

### EXTENSION OF 30 Mola RANGE OF TRIGONOMETRIC **FUNCTIONS**

to 
$$-\pi < \theta < \pi$$

Cosine of any angle

$$\cos \theta = \frac{1 - t^2}{1 + t^2}$$
 where  $t = \tan \frac{\theta}{2}$ 

Execution:

 $\theta / RUN / \cos \theta$ 

÷	G	00
#	3	01
2	2	02
	-	03
tan	9	04
X		05
+	E	06
#	3	07
1	1	80
÷	G	09
+	E	10
<u></u> .	F	11
#	3	12
1	1	13
# J≥ 0 0	-1	14
stop	0	15
•	Α	16
goto	2	17
0	0	18
0	0	19
MEX		20
enno	tito	21
net\V	ÚЯ	22
	3	23
		24
	9	25
stop	Q	26
X		27
mi		28
		29
step	- 0	30
7		31
goto	2	32
0	0	33
0	0	34
		35
	-	

# EXTENSION OF RANGE OF TRIGONOMETRIC FUNCTIONS

to 
$$-\pi < \theta < \pi$$

Tangent of any angle

$$\tan \theta = \frac{2t}{1-t^2}$$
 where  $t = \tan \frac{\theta}{2}$ 

Execution:

 $\theta$  / RUN / tan  $\theta$ 

•	G	00
#	3	01
2	2	02
=	_	03
tan	9	04
÷	G	05
(	6	06
X	•	07
× –	F	80
#	3	09
1	1	10
_	F	11
)	6	12
+	Е	13
=	- 13	14
stop	0	15
<b>V</b>	Α	16
goto	2	17
0	0	18
0	0	19
		20
110	1 hand	21
200 / 6	UR	22
		23
:		24
1		25
		26
		27
		28
		29
		30
		31
	1	32
		33
		34
		35

# EXTENSION OF RANGE OF TRIGONOMETRIC FUNCTIONS

to 
$$-\pi < \theta < \pi$$

sin, cos and tan using  $t = \tan \frac{\theta}{2}$ 

#### Execution:

 $\theta$  / RUN /  $\sin \theta$  / RUN /  $\cos \theta$  / RUN /  $\tan \theta$ 

÷	G	00
#	3	01
2	2	02
=	_	03
	9	04
tan	2	05
sto		06
X	E	06
+		
#	3	80
1	1	09
ंड	G	10
= 19814	11 <u>7 1</u> 181	11
ze <b>v</b> geb	Α	12
MEx	5	13
X	•	14
rcl	5	15
+	Е	16
- F	-	17
stop	0	18
•	A	19
MEx	5	20
+	E	21
_	E F 3	22
#	3	23
1	1	24
ni÷nle:	G	25
stop	0	26
X		27
rcl	5	28
=	_	29
stop	0	30
•	A	31
goto	2	32
0	0	33
0	0	34
		35
		00

# SINE AND COSINE OF ANY ANGLE

Sin: use program on right

Execution:

angle in degrees / RUN / sine

For radians version of program, insert  $/ \forall / R \rightarrow D$  / at beginning and omit / = / = / at end.

Cos: either use program on right and execute by

/ ▲▼ / ▲▼ / goto / 0 / 4 / angle in degrees /

RUN / cosine

or omit first four keystrokes of program on right and fill the empty spaces at the end with repeated / = / and execute by angle in degrees / RUN / cosine

For radians version of program, insert /  $\nabla$  / R $\rightarrow$ D / at the beginning.

*Note:* E can appear if reduced angles > 1.57 radians.

14	F	00
#	3	01
9	9	02
0	0	03
X	•	04
=	_	05
$\sqrt{X}$	1	06
, 1,	F	07
+	E	80
#	3	09
3	3	10
6	6	11
0	0	12
· , -2-	F	13
•	Α	14
gin	1	15
0	0	16
7	7	17
#	3	18
1 :	1	19
8	8	20
0	0	21
X		22
=	_ 1 F	23
$\sqrt{X}$	1	24 25
_	F	25
#	3	26
9	9	27
0	0	28
==	-	29
•	Α	30
D→R	3	31
sin	7	32
stop	0	33
=	-	34
=	_	35

## TANGENT OF ANY ANGLE

Execution:

angle in degrees / RUN / tangent

*Note:* E can appear if reduced angle > 1.57 radians.

+	E.	00
#	3	01
9	9	02
0	0	03
÷	G	04
(	6	05
×	. 6	06
=	_	07
$\sqrt{x}$ sto	_ 1	08
sto	2	09
)	6	10
-	F	11
Χ	F	12
it (su ,	6	13
rcl	5	14
a uno b	F	15
+	E	16
#	3	17
1	1	18
8	8	19
, 0	0	20
_	F	21
	Α	22
gin	1	23
1	1	24
5	5	25
#	3	26
9	9	27
0	0	28
=	_	29
•	Α	30
D→R	3	31
tan	9	30 31 32
)	6	33
=	_	34
stop	0	35

If all the hyperbolic functions are likely to be required, use the 'gudermannian' program on page 21 . For the individual functions, the following can be used:

Sinh x

Execution:

x / RUN / sinh x

Range:

 $-227.95 \le x \le 230.25$ 

•	Α	00
e×	4	01
e <sup>x</sup>	F	02
(	6	03
÷	G	04
)	6	05
÷ #	G	06
#	3	07
2	2	80
=	-	09
stop	0	10
	Α	11
goto	2	12
0	0	13
0	0	14
		15
1-120		16
esempeb	mi s	17
		18
08 450		19
	347.33	20
		21
		22
		23
		24 25
		26
		27
		28
		29
100		30
		31
		32
		33
		34
		35

Cosh x

Execution:

x / RUN / cosh x

Range:

 $-227.95 \le x \le 230.25$ 

•	Α	00
e×	4	01
e <sup>x</sup>	Е	02
(	6	03
	G	04
÷ )	6	05
	G	06
÷ #	3	07
2	2	08
to=	-	09
stop	0	10
•	Α	11
goto	2	12
0	0	13
0	0	14
		15
:110	3 100.	16
Ingr V b	Ufi	17
		18
	-86	19
700	1	20
range n	log	21
	2	22
		23
		24
-		25
		26
		27
		28
		29
		30
		31
		32
	3	33
	3	34
		35

Tanh x

Execution:

x / RUN / tanh x

Range:

|x| ≤ 113·97

+	E	00
- <del>-</del>	_	01
•	Α	02
e×	4	03
+	E	04
#	3	05
1	1	06
÷	G	07
+	Е	80
_	F	09
#	3	10
1	1	11
	F	12
=	_	13
stop	0	14
•	Α	15
goto	2	16
0	0	17
0	0	18
	. 991	19
PXPB	6.43	20
range n	t-of	21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

Sech x

Execution:

x / RUN / sech x

Range:

|x| ≤ 227·95

	A	00
e×	4	01
+	E	02
(	6	03
÷	G	04
)	6	05
÷	G	06
+	E	07
= 1	-	08
stop	0	09
▼	Α	10
goto	2	11
0	0	12
0	0	13
T X	me	14
goto i		15
0:80	i uni	16
	09	17
		18
		19
k 10*		20
27.95		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

Cosech x

Execution:

x / RUN / cosech x

Range:

1.0017 x  $10^{-4} \le |x| \le 227.95$  (|x| > 227.95 may give wrong result without E)

•	Α	00
e <sup>x</sup>	4	01
	F	02
(	6	03
÷	G	04
)	6	05
÷	G	06
+	Е	07
=	_	80
stop	0	09
•	Α	10
goto	2	11
0	0	12
0	0	13
144	x di	14
		15
- : nos	1101	16
Mac / M	UA.	17
0 0		18
	. 898	19
38.73	2 %	20 21
	14	21
	160	22
		23
	14	24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

Coth x

Execution:

x / RUN / coth x

Range:

 $1.0016 \times 10^{-4} \le |x| \le 113.97$ 

=	+	Е	00
▼ A 02 e <sup>×</sup> 4 03 - F 04 # 3 05 1 1 06 ÷ G 07 + E 08 + E 09 .# 3 10 1 1 11 = - 12 stop 0 13 ▼ A 14 goto 2 15 0 0 16 0 0 16 0 0 17		_	-
e <sup>×</sup>	•	Δ	-
- F 04 # 3 05 1 1 06 ÷ G 07 + E 08 + E 09 # 3 10 1 1 11 = - 12 stop 0 13 ▼ A 14 goto 2 15 0 0 16 0 0 17			
# 3 05 1 1 06	-		
1 1 06			
÷ G 07 + E 08 + E 09 # 3 10 1 1 11 = - 12 stop 0 13 ▼ A 14 goto 2 15 0 0 16 0 0 17 - 18 - 19 - 20 - 21 - 22 - 23 - 24 - 25 - 26 - 27 - 28 - 29 - 30 - 31 - 32 - 33 - 34			
+ E 08 + E 09 # 3 10 1 1 11 = - 12 stop 0 13 ▼ A 14 goto 2 15 0 0 16 0 0 17		_	
+ E 09 # 3 10 1 1 11 = - 12 stop 0 13 ▼ A 14 goto 2 15 0 0 16 0 0 17		-	-
# 3 10 1 1 11 = - 12 stop 0 13 ▼ A 14 goto 2 15 0 0 16 0 0 17			
1 1 11 = − 12 stop 0 13 ▼ A 14 goto 2 15 0 0 16 0 0 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33			-
=		_	
stop 0 13  ▼ A 14 goto 2 15 0 0 16 0 0 17 18 19 20 21 22 23 24 24 25 26 27 28 29 30 31 32 33 34		_	
▼ A 14 goto 2 15 0 0 16 0 0 17 18 19 20 21 22 23 24 24 25 26 27 28 29 30 31 31 32 33	stop	0	
goto         2         15           0         0         16           0         0         17           18         19           20         21           22         23           24         25           26         27           28         29           30         31           32         33           34         34		_	
0 0 16 0 0 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33		-	
0 0 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 31 32			
18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33			17
20 21 22 23 24 25 26 27 28 29 30 31 32 33	8010	1	
21 22 23 24 25 26 27 28 29 30 31 32 33		. 0	19
22 23 24 25 26 27 28 29 30 31 32 33 34			20
23 24 25 26 27 28 29 30 31 32 33 34			21
23 24 25 26 27 28 29 30 31 32 33 34			22
24 25 26 27 28 29 30 31 32 33			
25 26 27 28 29 30 31 32 33 34			
26 27 28 29 30 31 32 33 34			25
27 28 29 30 31 32 33 34			
28 29 30 31 32 33 34			
30 31 32 33 34			
31 32 33 34			29
31 32 33 34			30
33 34			31
34			
-			
35			No. of Concession, Name of Street, or other Designation, Name of Street, Name
			35

All the hyperbolic functions

#### Execution:

x / RUN / sinh x / RUN / cosech x / RUN / cosh x / RUN / sech x / RUN / tanh x / RUN / coth x /

#### Range:

 $1.0017 \times 10^{-4} \le |x| \le 7.8566$ 

~	Α	00
e <sup>x</sup>	4	01
+	E	02
#	3	03
1	1	04
÷	G	05
+	Е	06
-	F	07
#	3	08
1	1	09
-	F	10
9=0	2	11
•	Α	12
arctan	9	13
+	Е	14
=	_	15
sto	2	16
tan	9	17
stop	0	18
•	G	19
1919	Ш	20
stop	0	21
rcl	5	22
cos	8	23
÷	G	24
=	-	25
stop	0	26
÷	G	27
=	_	28
stop	0	29
rcl	5	30
sin	7	31
stop	0	32
÷	G	33
=	_	34
stop	0	35

#### The gudermannian program

Enables all the hyperbolic functions to be calculated with suitable execution sequences.

#### Formulae:

$$gdx = 2 \arctan \tanh \frac{x}{2}$$

$$sinh x = tan gdx$$

$$cosech x = cot gd x$$

$$cosh x = sec gd x$$

$$sech x = cos gdx$$

$$tanh x = sin gdx$$

$$coth x = cosec gdx$$

#### Execution:

x / RUN / gd x / ▲▼ / tan / sinh x / ÷ / = / cosech x

This program can be used inside parentheses and does not affect memory.

Accuracy is less than that of individual hyperbolic function programs.

#### Range:

$$|x| \le 227.95$$
 for gd x

 $|x| \le 7.8566$  for hyperbolic functions

•	Α	00
e×	4	01
+	Е	02
#	3	03
1	1	04
÷	G	05
+	E	06
#	F	07
#	3	80
1	1	09
00 1 9	F	10
=	_	11
<b>V</b>		12
arctan	9	13
+	Е	14
00 <b>=</b> %	_	15
stop	0	16
~	Α	17
goto	2	18
0	0	19
0	0	20
		21
ormule		22
enal tea	110:	23
	- 0	24
	198	25
	x f	26
	U.F	27
		28
	1	29
PU A	110	30
8	X	31
381		32
	X	33
	5	34
		35

# INVERSE HYPERBOLIC FUNCTIONS

All the inverse hyperbolic functions can be obtained from the following program.

#### Execution:

#### Range:

sinh <sup>-1</sup> x	$10^{-49} \leqslant  x  \leqslant 577.$	35
cosh <sup>-1</sup> x	$1 \le x \le 3162 \cdot 2$	No E if x —ve
tanh <sup>-1</sup> x	$-0.99999 \leqslant x \leqslant 0$	.99999
cosech <sup>-1</sup> x	$0.001732 \le  x  \le$	10 <sup>49</sup>
sech <sup>-1</sup> x	3·162278 x 10 <sup>-4</sup> ≤	≤ x ≤ 1
	No E if x —ve	
coth <sup>-1</sup> x	$1.0001 \leqslant  x  \leqslant 10$	99

÷	G	00
X	•	01
3-23	F	02
+ #	E	03
#	3	04
1	1	05
=	_	06
$\sqrt{X}$	1	07
•	Α	08
goto	2	09
2	2	10
0	0	11
÷	G	12
X	. 10	13
+ #	Е	14
#	3	15
1	_1	16
= \sqrt{X}	-	17
$\sqrt{X}$	1	18
g ó <del>é</del> co	G	19
_	F	20
+	Ε	21
#	3	22
1	1	23
÷	G	24
+	Е	25
so <del>4</del> 6%	F	26
#	3	27
1	1	28
onu= si	-	29
$\sqrt{X}$	1	30
In	4	31
stop	0	32
et <del>e</del> 88	F	33
=	F -	34
stop	0	35

<sup>\*</sup> For negative x press / RUN / a second time when evaluating sinh<sup>-1</sup> x and cosech<sup>-1</sup> x to get the correct answer.

# MODULO ARITHMETIC ('Clock Arithmetic')

Base 7 is used as an example.

The program completes a calculation and works out the remainder when the result is divided by 7. Neither the brackets nor the memory are used, so that the operation of / RUN / is exactly that of / = /.

For other bases, insert the base at steps 03, 11 and 14. Change the address at steps 18 and 19 to 14 if a two digit base is used, 16 for a three digit base, etc.

Execution may take a long time if very large numbers are involved.

#### Example:

/3/X/5/RUN/1/+/8/RUN/2/etc.

	,		-	0	
_	1	=	_	00	
+	-			)1	
#	-	3 7		)2	
7		7	_	)3	
_		F		)4	
•	4	Α	⊢	)5	
gin	-	1	_	06	
0	L	0	-	07	
0	L	0	+	80	
neughir		F	_	09	
#		3		10	
7		7		11	
+		E	1	12	
#		3		13	
7		3 7		14	
				15	
	T	Α	I	16	
gin	I	1		17	,
1	8	1		18	3
2		2		19	
stop	1	0		20	
•	1	A		21	
goto				22	2
0	1	2		23	
0		0		24	1
tosm s		3 6		2!	5
1111		7		20	6
	100	139		2	7
1.000000			500	2	8
				2:	9
				3	C
- 19		A		3 3	1
9010		1		3	2
		0		3	3
14		1		3	
	_	T		3	_
					•

### PRIME FACTORISATION

To find the prime factors of a number N.

#### Pre-execution:

2 / AV / sto / AV / goto / 0 / 0 / C/CE /

#### Execution:

 $N / RUN / a_1 / RUN / N_1 / RUN / a_2 / RUN / N_2 / \cdots / a_r / RUN / 1$ 

#### where

 $a_1, a_2, a_3, \cdots a_r$  are the prime factors of N and

 $N_1, N_2, \cdots$  are the residues defined by

$$N_1 = \frac{N}{a_1}$$
,  $N_2 = \frac{N}{a_1 a_2}$ ,  $N_3 = \frac{N}{a_1 a_2 a_3}$ , etc.

Pressing / RUN / after 1 has been displayed will cause the machine to go into an infinite loop.

Warning: Long execution times are possible for large values of N or for numbers with large prime factors.

÷.	G	00
(	6	01
3	F E 5	02
+	E	03
rcl	5	04
_	F A	05
	Α	06
gin	1	07
0	0	80
2 = •	2	09
a bettu e	-	10
•	A	11
gin	1	12
2	2	13
4	2 4	14
rcl	5	15
stop	0	16
er l(eses	6	17
00510	\$ <u></u>	18
stop	0	19
•	Α	20
goto	2	21
0	0	22
0	0	23
rcl	5	24
UA+a\	E	25
#	3	26
1	1	27
=	_	28
sto	2	29
#	3	30
1	1	31
=	_	32
)	6	33
=	-	34
=	_	35

### PRIME NUMBER TESTING

To find whether a number n is prime, choose any integer  $m \ge \sqrt{n}$ .

Then use the execution sequence:

n/RUN/m/RUN/

The result will be the largest number less than or equal to m which divides n. If the result is 1 then n is prime.

To test another number, pre-execute with:

/ AV / AV / goto / 0 / 0 /

*Note:* Long execution times are possible for large numbers.

2	00
0	01
Α	02
5	03
	04
	05
	06
	07
	80
	09
	10
	11
	12
6	13
4	14
Α	15
	16
2	17
1	18
5	19
	20
	21
F	22
3	23
1	24
_	25
	26
3	27
0	28
	29
6	30
Α	31
	32
0	33
4	34
	35
	0 A 5 E 6 F E 5 F A 1 0 6 - A 1 2 1 5 0 5 F 7 3 1 1 - 2 3 0 0 - 1 1 - 1 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

### **FACTORIALS**

Execution:

n / RUN / n!

Restriction:

1 ≤ n ≤ 69

Note: The program may be used within brackets. It does, however, use the memory. Thus, to calculate

15! 6! 10!

a possible execution sequence is:

15 / RUN / ÷ / ▲▼ / ( / 10 / RUN / ▲▼ / ) / ÷ / ▲▼ / ( / 6 / RUN / ▲▼ / ) / = / answer

sto	2	00
	F	01
#	3	02
2	2	03
+	Е	04
•	Α	05
gin	1	06
2	2	07
1	2	80
#	3	09
1	3	10
X	i.	11
•	Α	12
MEx	A 5	13
xe =rit :	811	14
▼	Α	15
MEx	5	16
•	Α	17
goto	2	18
0	0	19
1	1	20
=	-	21
rcl	5	22
stop	0	23
Vicio	Α	24
goto	2	25
0	0	26
0	0	27
		28
25.00	-	29
		30
		31
		32
		33
		34
		35

### FACTORIALS OF LARGE NUMBERS

This program calculates In (n!) for n greater than about 25.

Reasonably accurate results are given for n greater than 10.

(The program uses, Stirling's approximation,  $n! = \sqrt{2\pi n} e^{-n} n^n$ )

Execution:

n / RUN / In (n!)

sto	2	00
+	Е	01
#	3	02
	Α	03
5	5	04
X		05
(	6	06
rcl	5	07
In	4	80
)	6	09
_	F	10
rcl	5	11
+	Е	12
#	3	13
+1.)	Α	14
9	9	15
1	1	16
8	8	17
9	9	18
ius=d b	ш	19
stop	0	20
id <b>v</b> vie	Α	21
goto	2	22
0	0	23
0	0	24
		25
t zsvig	Ĉ	26
n zevin	00	27
		28
		29
00 \ %		30
2121	91 18	31
6	1-5	32
6		33
5 1 USS		34
		35

# THE GAMMA AND PI FUNCTIONS

$$\Gamma (n + 1) = \pi(n) = n!$$
 when n is an integer 
$$\Gamma (x + 1) = x \Gamma(x)$$
 for  $x > 0$  
$$\Gamma (0)$$
 is undefined 
$$\pi (0) = \Gamma (1) = 1$$
 
$$\Gamma (\frac{1}{2}) = \sqrt{\pi}$$
 
$$\pi (\frac{1}{2}) = \frac{1}{2} \sqrt{\pi}$$
 
$$\pi (1) = \Gamma (2) = 1$$

#### By interpolation:

$$\Gamma (n + \delta) \triangleq (n + \frac{1}{2}\delta - \frac{1}{2})^{\delta} \Gamma (n) \qquad 0 \le \delta \le 1$$

$$\therefore \pi (\delta) \triangleq (n + \frac{1}{2}\delta - \frac{1}{2})^{\delta} \prod_{r=1}^{n-1} \frac{(r)}{r+\delta} \quad 0 \le \delta \le 1$$

$$\Gamma (\delta) = \frac{\pi (\delta)}{\delta} \triangleq \frac{(n + \frac{1}{2}\delta - \frac{1}{2})^{\delta}}{\delta} \prod_{r=1}^{n} \frac{r}{(r+\delta)}$$

$$0 \le \delta \le 1$$

n should be suitably large for the accuracy required.

n = 20 gives high accuracyn = 5 gives reasonable accuracy for most purposes

e.g. 
$$\pi (\frac{1}{2}) = \frac{1}{2}\sqrt{\pi} = 0.8862269$$
  
n = 5 gives  $\pi (\frac{1}{2}) = 0.885547$   
n = 20 gives  $\pi (\frac{1}{2}) = 0.8861174$ 

#### Execution:

$$\begin{array}{c|c} \blacktriangle \blacktriangledown / \blacktriangle \blacktriangledown / \operatorname{goto} / 0 / 0 / \\ n / \mathsf{RUN} / \delta / \mathsf{RUN} / n - 1 / \mathsf{RUN} / n - 2 / \\ \mathsf{RUN} / \cdots / 2 / \mathsf{RUN} / 1 / \mathsf{RUN} / \pi (\delta) / \blacktriangle \blacktriangledown / \\ \blacktriangle \blacktriangledown / \operatorname{goto} / 3 / 2 / \mathsf{RUN} / \Gamma (\delta) \end{array}$$

+	E	00
+	E E 0	01
stop		02
sto	2	03
_	F	04
#	3	05
1	1	06
÷ #	G	07
#	3	08
2	2	09
=	-	10
In	4	11
X		12
rcl	5	13
95=ne	da_r	14
<b>▼</b> e <sup>×</sup>	Α	15
e×	4	16
÷	G	17
(	6	18
stop	0	19
÷	G	20
rcl	5	21
÷ +	G	22
+	Е	23
#		24
1	3	24 25
=	-	26
)	6	27
•	Α	28
▼ goto	2	29
1	1	30
7	7	31
7 rcl	5	32
.)	6	33
=	_	34
stop	0	35

### FIBONACCI NUMBERS

sto	2	00
#	3	01
1	1	02
+	Е	03
stop	0	04
•	Α	05
MEx	5	06
•	Α	07
goto	2	80
0	0	09
3	3	10
		11
		12
		13
		14
		15
		16
		17
		18
		19
		20
		21
		22
		23
		24
a iyo iq		25
ргодга	08	26
	20 kg	27
		28
		29
		30
		31
rel		32
2122		33
		34
		35

Each number in the sequence is the sum of the previous two.

#### Execution:

C/CE / RUN / F1 / RUN / F2 / RUN / · · ·

**Decimal to binary (fractions)** 

Given a decimal x,  $0 \le x \le 1$ , this program calculates the binary expansion of x to any number of places.

Suppose 
$$x = 0 \cdot d_1 d_2 \dots$$
 (binary)

#### Execution:

$$x / RUN / d_1 / RUN / d_2 / RUN / d_3 / \cdots$$

To calculate the expansion of another decimal y, press

/<sup>C</sup>/CE / <sup>C</sup>/CE / ▲▼ / goto / 0 / 0 / y / RUN / · · · etc.

#### Notes:

- To convert decimal integers to binary use the program on page 31.
- No program for converting decimal fractions to bases other than 2 is provided.

sto	2	00
#	3	01
1	1	02
=	_	03
	А	04
MEx	5	05
_	5 F 6	06
(	6	07
rcl	5	80
÷	G	09
÷ #	3	10
2	2 - 2	11
=	-	12
sto	2	13
)	6	14
in <u>L</u> em	F 6	15
(	6	16
▼:00	Α	17
gin	1	18
2	2	19
4 #	4	20
#	3	21
1	1	22
+ •	Ε	23 24
#	3	24
0	0	25
X		26
stop	0	27
rcl	5	28
)	6	29
+	Е	30 31
rcl	E 5	31
•	Α	32
goto 0	2	33
0	0	34
6	6	35

Decimal integer to base m

This program expresses any integer in any base.

Suppose  $x = a_1 \cdot \cdot \cdot \cdot a_r$  in base m.

Execution:

m / RUN / x / RUN /  $a_r$  / RUN /  $a_{r-1}$  / ···· /  $a_1$  / RUN / m

Note that the digits are produced in reverse order and that the machine tells you that all the digits have been shown by displaying the base m.

The sequence can be repeated for a new x and/or m. If the same m is required there is no need to re-enter it because it is already in the display.

*Note:* To convert decimal fractions to base 2, use the program on page 30.

sto	2	00
stop	0	01
_	F	02
(	6	03
+	Е	04
#	3	05
1	1	06
_	F	07
+	Е	08
rcl	5	09
-	F	10
•	Α	11
gin	1	12
0	0	13
7	7	14
+	E	15
rcl	5	16
	F	17
#	3	18
1	1	19
=	_	20
)	6	21
stop	0	22
÷	G	23
rcl	5	24
_	F	25
_	F	26
₩ "	F	27
gin	1	28
0	0	29
2	2	30
=	_	31
rcl	_ 5	32
stop	0	33
=	_	34
=	_	35

Binary to decimal (integers)

Binary is  $a_n \cdot \cdot \cdot a_o$ 

Execution:

 $a_n / RUN / a_{n-1} / RUN / \cdots / a_o / = / answer$ 

	+	Е	00
	+	E	01
	stop	0	02
	•	Α	03
	goto	2	04
	0	0	05
	0	0	06
		-8	07
	tot	5	80
		10	09
	gram e	PIG	10
	2	2	11
	10 ×	1000	12
	Maga	a.	13
			14
	1212	¥.	15
			16
	n the c		17
	ngih b		18
	ised evi		19
	. 4		20
	o agnot	Dec	21
			22
	<del>5000   11</del>	16177	23
	avniša o	73.	24
	nangono	eri	-
			26
	-8100		27
	ere i		28
			29
		2	30
	200		31
		6	32
	e de la companya del companya de la companya del companya de la co		33
		4	34
		0	35
I			33

Binary fraction to decimal

If number is:

 $0 \cdot b_1 b_2 \cdot \cdot \cdot b_k$ 

Execution:

 $RUN/b_1/RUN/b_2/\cdots/b_k/RUN/answer$ 

At each stage the answer so far is displayed.

#### Fraction base m to decimal

Exactly the same except / 2 / at step 10 is replaced by the appropriate base.

#	3	00
1	1	01
=	_	02
sto	2	03
(	6	04
stop	0	05
•	Α	06
MEx	5	07
÷	G	08
# 2 . X	3	09
2.	2	10
X	•	11
•	Α	12
MEx	5	13
)	6	14
+	Е	15
	Α	16
goto	2	17
	2	1/
0	0	17 18
		18 19
0	0	18 19 20
0	0	18 19
0	0	18 19 20
0	0	18 19 20 21
0	0	18 19 20 21 22
0	0	18 19 20 21 22 23
0	0	18 19 20 21 22 23 24
0	0	18 19 20 21 22 23 24 25
0	0	18 19 20 21 22 23 24 25 26
0	0	18 19 20 21 22 23 24 25 26 27
0	0	18 19 20 21 22 23 24 25 26 27 28 29 30
0	0	18 19 20 21 22 23 24 25 26 27 28 29 30 31
0	0	18 19 20 21 22 23 24 25 26 27 28 29 30
0	0	18 19 20 21 22 23 24 25 26 27 28 29 30 31
0	0	18 19 20 21 22 23 24 25 26 27 28 29 30 31 32

Binary to decimal (integers, fractions or mixed numbers)

Binary is  $a_n \dots a_o \cdot b_1 \dots b_m$ 

#### Execution:

 $C_{CE}$  / RUN /  $a_n$  / RUN /  $a_{n-1}$  / RUN / · · · · / RUN /  $a_o$  / — / RUN /  $b_1$  / RUN /  $b_2$  / · · · · /  $b_m$  / RUN / answer

#### Notes:

- The / / corresponding to the 'decimal' point must be entered even if the number is an integer.
- 2. The correct answer will be given if:

#### To re-use:

C/CE / C/CE / ▲▼ / ▲▼ / goto / 0 / 0

the contract of the contract o		
+	Е	00
+	Е	01
stop	0	02
_	F	03
- : :	F	04
•	Α	05
gin	1	06
0	0	07
0	0	80
sto	2.	09
= .		10
#	3	11
1 1 1 1 1 1	1	12
.=	7	13
•	Α	14
MEx	5	15
U+	Е	16
(	6	17
stop	0	18
▼ .	Α	19
MEx	5	20
÷	G	21
#	3	22
2	2	23
X		24
▼	Α	25
MEx	5	26
)	6	27
▼ .	Α	28
goto	2	29
1	1	30
6	6	31
		32
-		33
	-	
		34 35

Base m to decimal (integers)

Number is  $a_n a_{n-1} \cdots a_o$ 

Execution:

 $m/RUN/a_n/RUN/a_{n-1}/RUN/\cdots/a_n/$ = / answer

To re-use with same m: RUN / ac \_ , / · · · / RUN / ac

C/CE / RUN / a' · · ·

	_	
sto	2	00
stop	0	01
X		02
rcl	5	03
+	Е	04
<b>V</b>	Α	05
goto	2	06
0	0	07
1	1	08
		09
	11 9	10
	. 0	11
	1 0	12
		13
l a lai		14
	7000	15
	elan	16
		17
		18
	eisus	19
	191	20
	AUS	21
		22
		23
	138	24
	ini	25
Inite no	. 31	26
	am	27
	eris	28
	And Y	29
		30
		31
		32
		33
		34
		35

Base m to decimal (integers, fractions or mixed numbers)

Number is:  $a_n \dots a_o \cdot b_1 \dots b_p$ 

#### Example:

m = 7

#### Execution:

 $^{G}$ CE / RUN /  $a_n$  / RUN /  $a_{n-1}$   $/ \cdots$  / RUN /  $a_o$  / - / RUN /  $b_1$  / RUN /  $b_2$   $/ \cdots$  / RUN /  $a_n$ swer

#### Notes:

- 1. Insert value of m at 02 and 25.
- 2. If two digit base is used, insert at 02, 03, move the next 22 steps down one, insert the base again at 26, 27, and substitute / 1 / 9 / for / 1 / 8 / in the last two steps.

X	•	00
#	3	01
7	7	02
+	Е	03
stop	0	04
_	F	05
<u> </u>	F	06
	E 0 F F A 1	07
gin	1	80
0	0	09
0	0	10
sto	2	11
=	_	12
#	3	13
1	1	14
<b>=</b>	_	15
•	Α	16
MEx	A 5 E 6	17
+	Е	18
(	6	19
stop	0	20
1.s <b>▼</b> 1/1	Α	21
MEx	5	22
•	G	23
#	3	24
7	7	25
X		26
÷ # 7 ×	Α	27
MEx	5	28
)	6	29
	Α	30
▼ goto	2	31
1	1	32
8	8	33
		34
		35

#### Natural numbers

$$(1+2+\cdots+n)=\frac{1}{2}n(n+1)$$

#### Execution:

n / RUN / sum

+	E	00
(	6	01
X		02
)	6	03
÷	G	04
#	3	05
2	2	06
=	4	07
stop	0	08
	Α	09
goto	2	10
0	0	11
0	0	12
		13
		14
		15
		16
		17
		18
		19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

#### Squares of natural numbers

$$(1+4+9+\cdots+n^2)=\frac{1}{6}n(n+1)(2n+1)$$

Execution:

n / RUN / sum

sto	2	00
+	Е	01
+	Е	02
#	3	03
3	3	04
X		05
rcl	5	06
+	Е	07
#	3	80
1	1	09
X	9	10
rcl	5	11
*	G	12
#	3	13
6	6	14
	1-5	15
stop	0	16
<b>V</b>	Α	17
goto	2	18
0	0	19
0	0	20
	Á	21
MEX	1	22
-	10	23
*	3	24
7.	7	25
× .		26
*	A	27
MEX	5	28
	8	29
197	A	30
1977	2	31
1	1	32
- 8	8	33
		34
		35
-	-	_

#### **Cubes of natural numbers**

$$(1+8+27+\cdots n^3)=\frac{1}{4}n^2(n+1)^2$$

Execution:

n / RUN / sum

	_	_
+	E	00
(	6	01
X	•	02
. )	6	03
X		04
÷	G	.05
#	3	06
4	4	07
8=20	-0	08
stop	0	09
ु ▼ः	Α	10
goto	2	11
0	0	12
0	0	13
	SITT	14
		15
7+81	4 =	16
		17
1 17927		18
		19
2 / X4 / /	1141	20
		21
	-	22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

## **ARITHMETIC SERIES**

First term = a Common difference = d N terms

$$sum = N\left(a + \frac{(N-1)d}{2}\right)$$

#### Execution:

a / RUN / N / RUN / d / RUN / sum

+	E	00
(	6	01
stop	0	02
sto	2	03
-	F	04
#	3	05
1	1	06
÷	G	07
#	3	80
2	2	09
X		10
stop	0	11
)	6	12
×	:	13
rcl	5	14
=	-	15
stop	0	16
•	Α	17
goto	2	18
0	0	19
0	0	20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

## ARITHMETIC SERIES

First term = a Last term = 1 N terms  $sum = \frac{N(a+1)}{2}$ 

Execution:

a / RUN / I / RUN / N / RUN / sum

+	E	00
stop	0	01
÷	G	02
#	3	03
2	2	04
× .		05
stop	0	06
=	_	07
stop	0	80
•	Α	09
goto	2	10
0	0	11
0	0	12
		13
		14
		15
	35,7793	16
		17
		18
		19
		20
100	olitu	21
91-1	MH	22
		23
		24
		25
		26
		27
		28
		29
	1	30
		31
		32
		33
		34
		35

## GEOMETRIC SERIES

$$S = a + ar + \cdots + ar^{N-1} = \frac{a(1-r^n)}{(1-r)}$$

First term = a

Common ratio = r

N terms

Restrictions:

r > 0,  $r \neq 1$ 

Execution:

a/RUN/r/RUN/N/RUN/sum

	0	00
÷	G	00
(	6	01
stop	0	02
sto	2	03
_	F	04
#	3	05
1	1	06
7 -= ,	_	07
)	6	80
X	•2	09
(	6	10
rcl	5	11
In	4	12
X	ien	13
stop	0	14
=	5111	15
-	Α	16
e×	4	17
-010	4 F	18
#	3	19
JE 10 \	1	20
=	_	20 21
)	6	22
=	_	23
stop	0	24
▼	A	25
goto	2	26
0	0	27
0	0	28
	-	29
		30
		31
		32
		33
		34
		35
		35

## INFINITE GEOMETRIC SERIES

$$S = a + ar + ar^2 + \dots = \frac{a}{1 - r}$$

Restriction:

|r| < 1

Execution:

a / RUN / r / RUN / sum

÷	0	00
	G	00
(	6	01
#	3	02
1	1	03
	F	04
stop	0	05
)	6	06
=	_	07
stop	0	80
-	Α	09
goto	2	10
0	0	11
. 0	0	12
		13
Mab		14
1		15
		16
		17
.110	itor	18
	1	19
	- 10	20
10	olitu	21
A VBV	ИÜ	22
1983		23
		24
		25
		26
		27
		28
	A	29
		30
- 0	10	31
	U	32
		33
rei	5	34
stop		35
		33

# ARITHMETIC — GEOMETRIC SERIES (infinite)

$$S = a + (a + d)r + (a + 2d)r^{2} + \dots + (a + nd)r^{n} + \dots$$

$$a + \frac{dr}{dr}$$

$$= \frac{a + \frac{dr}{1 - r}}{1 - r}$$

Restriction:

|r| < 1

Execution:

r/RUN/d/RUN/a/RUN/sum

	F	00
#	3	01
1	1	02
	F	03
÷	G	04
X		05
(	6	06
_	F	07
#	3	08
1	1	09
X		10
stop	0	11
+	E	12
stop	0	13
)	6	14
=	_	15
stop	0	16
-	Α	17
goto	2	18
0	0	19
0	0	20
		21
		22
		23
		24
		25
		26
- 6	0	27
0	n	28
		29
		30
		31
		32
		33
		34
		35

## SUMMING SERIES IN GENERAL

 $\sum_{n=1}^{N} a(n)$ , some function a.

#### Examples:

1. 
$$1+4+9+\cdots+N^2$$
 a(n

2. 
$$\left(1 + \frac{1}{1}\right) + \left(8 + \frac{1}{4}\right) + \dots + \left(N^3 + \frac{1}{N^2}\right)$$
  

$$a(n) = n^3 + \frac{1}{n^2} \qquad \text{etc.}$$

Write a program segment which evaluates a(n) when n is in memory; parentheses may not be used. The segment may be up to 15 steps long, any final / = / stop / being omitted. Fill up any unused steps with  $/ = / \cdots / = /$ .

#### Examples for above:

1. 
$$n^2$$
 rcl / X /

2. 
$$n^3 + \frac{1}{n^2}$$
 write as  $(n^5 + 1) \div n^2$   
 $rcl / X / X / X / rcl / + / # / 1 / \div / rcl / rcl /$   
 $= / = / = /$ 

Then use the program as shown.

#### Pre-execution:

Clear memory with C/CE / ▲▼ / sto /

#### Execution:

$$N/RUN/a(1) + a(2) + \cdots + a(n)$$

_	00
Α	01
5	02
Е	03
6	04
	05
	06
	07
	80
	09
	10
	11
8703	12
	13
- 1	14
	15
	16
	17
	18
	19
6	20
-	21
	22
5	23
	24
	25
	26
F	27
	28
Α	29
	30
	31
0	32
_	33
	34
0	35

$$a(x_1) + a(x_2) + \cdots + a(x_n)$$

Write a program segment to evaluate  $a(x_i)$  without using parentheses; the memory may be used.

Then use the following program:

Execution:

$$RUN/x_1/RUN/x_2/\cdots/x_n/RUN/sum$$

At each step the sum so far is displayed.

Example:

To find 
$$\Sigma \tan \left(x^2 + \frac{1}{x}\right)$$

Express 
$$x^2 + \frac{1}{x}$$
 as  $\frac{x^3 + 1}{x}$ 

Program segment is then:

/ sto / 
$$\times$$
 /  $\times$  / rcl / + / # / 1 /  $\div$  / rcl / = / tan / and so program is as shown.

The segment may be up to 32 steps long, by omitting  $/ \nabla / goto / 0 / 0 / at the end and filling any empty steps with <math>/ = /$ .

(	6		00
stop	0	)	01
sto	2		02
X			03
X			04
rcl	5		05
+	Е		06
#	3		07
1	1		08
÷	G		09
rcl	5		10
=	-		11
tan	9		12
) .	6	200	13
+	Е		14
ns <b>v</b> oid	Α	90	15
goto	2	-	16
0	0		17
0	0		18
			19
		1	20
		2	21
		2	22
			23
10		2	24
XXX		2	25
\ = \ =		2	26
cou oa	AT	2	27
		2	8
inaitu	юx	2	29
LANA MA	/23	3	0
		3	1
100	itu	3	2
4141	411	3	3
		3	4
		3	5

## HARMONIC ADDITION

Resistors in parallel, capacitors in series, lenses in series, etc.

$$\frac{1}{x} = \frac{1}{x_1} + \dots + \frac{1}{x_n}$$

Execution:

$$x_1 / RUN / x_2 / RUN / \cdots / x_n / RUN / x$$

At each step the harmonic sum so far is displayed.

	-	00
÷	G	00
+	Е	01
(	6	02
÷	G	03
=	_	04
stop	0	05
÷	G	06
)	6	07
•	Α	08
goto	2	09
0	0	10
1	1	11
		12
		13
		14
		15
		16
		17
1971	14.0	18
de massi		19
		20
		21
		22
		23
adva II		24
0		25
	- 7	26
		27
		28
		29
		30
		31
		32
		33
		34
		35

## PYTHAGOREAN ADDITION

Geometry, electricity

$$x = \sqrt{x_1^2 + \dots + x_n^2}$$

Execution:

 $x_1 / RUN / x_2 / RUN / \cdots / x_n / RUN / x$ 

At each step the intermediate result  $\sqrt{x_1^2 + \cdots + x_i^2}$  is displayed.

X				00
+		Е		01
(		6		02
$\sqrt{X}$	-	1		03
stop		0		04
×				05
)		6		06
•		Α		07
goto		2		80
0		0		09
1		1		10
				11
ald m			1	12
			1	13
				14
				15
			1	16
				17
				18
				19
				20
				21
				22
	I			23
				24
				25
	L			26
	L		1	27
	L			28
			1	29
				30
				31
				32
	L		┿	33
				34
			3	35

## ARITHMETIC MEAN

Pre-execution:

C/CE / C/CE / ▲▼ / ▲▼ / goto / 0 / 0

Execution:

 $x_1 / RUN / x_2 / RUN / \cdots / x_n / RUN /$ arithmetic mean

At each stage the arithmetic mean so far is displayed.

X	•	00
(	6	01
#	3	02
1	1	03
=	1	04
sto	2	05
)	6	06
+	Е	07
(	6	08
stop	0	09
÷	G	10
rcl	5	11
)	6	12
·	G	13
(	6	14
#	3	15
1	1	16
+	Е	17
rcl	5	18
÷	G	19
•	Α	20
MEx	5	21
. )	6	22
•	Α	23
goto	2	24
0	0	25
7	7	26
	A	27
		28
	0	29
1	8 ]	30
		31
		32
		33
		34
		35

## GEOMETRIC MEAN

Pre-execution:

C/CE / C/CE / AV / goto / 0 / 0

Execution:

 $x_1 / RUN / x_2 / RUN / \cdots / x_n / RUN /$ geometric mean

At each stage the geometric mean so far is displayed.

In			-
( 6 02 # 3 03 1 1 04 = - 05 sto 2 06 ) 6 07 + E 08 ( 6 09 ▼ A 10 e <sup>x</sup> 4 11 stop 0 12 In 4 13 ÷ G 14 rcl 5 15 ) 6 16 ÷ G 17 ( 6 18 # 3 19 1 1 20 + E 21 rcl 5 22 ÷ G 23 ▼ A 24 MEx 5 25 ) 6 26 ▼ A 27 goto 2 28 0 0 29 8 8 30 31 32 33 34		_	00
# 3 03 1 1 04 = - 05 sto 2 06 ) 6 07 + E 08 ( 6 09 ▼ A 10 e* 4 11 stop 0 12 In 4 13 ÷ G 14 rcl 5 15 ) 6 16 ÷ G 17 ( 6 18 # 3 19 1 1 20 + E 21 rcl 5 22 ÷ G 23 ▼ A 24 MEx 5 25 ) 6 26 ▼ A 27 goto 2 28 0 0 29 8 8 30 31 32 33 34			01
1 1 04 = - 05 sto 2 06 ) 6 07 + E 08 ( 6 09 ▼ A 10 e <sup>x</sup> 4 11 stop 0 12 In 4 13 ÷ G 14 rcl 5 15 ) 6 16 ÷ G 17 ( 6 18 # 3 19 1 1 20 + E 21 rcl 5 22 ÷ G 23 ▼ A 24 MEx 5 25 ) 6 26 ▼ A 27 goto 2 28 0 0 29 8 8 30 31 32 33 34		6	02
=	#	3	03
sto 2 06 ) 6 07 + E 08 ( 6 09 ▼ A 10 e* 4 11 stop 0 12 In 4 13 ÷ G 14 rcl 5 15 ) 6 16 ÷ G 17 ( 6 18 # 3 19 1 1 20 + E 21 rcl 5 22 ÷ G 23 ▼ A 24 MEx 5 25 ) 6 26 ▼ A 27 goto 2 28 0 0 29 8 8 30 31 32 33 34	1	1	04
) 6 07 + E 08 ( 6 09 ▼ A 10 e <sup>x</sup> 4 11 stop 0 12 In 4 13 ÷ G 14 rcl 5 15 ) 6 16 ÷ G 17 ( 6 18 # 3 19 1 1 20 + E 21 rcl 5 22 ÷ G 23 ▼ A 24 MEx 5 25 ) 6 26 ▼ A 27 goto 2 28 0 0 29 8 8 30 31 32 33 34	=	_	05
+ E 08 ( 6 09 ▼ A 10 e <sup>x</sup> 4 11 stop 0 12 In 4 13 ÷ G 14 rcl 5 15 ) 6 16 ÷ G 17 ( 6 18 # 3 19 1 1 20 + E 21 rcl 5 22 ÷ G 23 ▼ A 24 MEx 5 25 ) 6 26 ▼ A 27 goto 2 28 0 0 29 8 8 30 31 32 33 34		2	06
( 6 09 ▼ A 10 e <sup>x</sup> 4 11 stop 0 12 In 4 13 ÷ G 14 rcl 5 15 ) 6 16 ÷ G 17 ( 6 18 # 3 19 1 1 20 + E 21 rcl 5 22 ÷ G 23 ▼ A 24 MEx 5 25 ) 6 26 ▼ A 27 goto 2 28 0 0 29 8 8 30 31 32 33 34	)	6	07
▼ A 10  e <sup>x</sup> 4 11  stop 0 12  In 4 13  ÷ G 14  rcl 5 15  ) 6 16  ÷ G 17  ( 6 18  # 3 19  1 1 20  + E 21  rcl 5 22  ÷ G 23  ▼ A 24  MEx 5 25  ) 6 26  ▼ A 27  goto 2 28  0 0 29  8 8 30  31  32  33  34	+	Е	08
e <sup>x</sup> 4 11 stop 0 12 In 4 13 ÷ G 14 rcl 5 15 ) 6 16 ÷ G 17 ( 6 18 # 3 19 1 1 20 + E 21 rcl 5 22 ÷ G 23 ▼ A 24 MEx 5 25 ) 6 26 ▼ A 27 goto 2 28 0 0 29 8 8 30 31 32 33 34	(	6	09
stop 0 12 In 4 13		Α	10
In 4 13		4	11
In 4 13	stop	0	12
rcl 5 15 ) 6 16 ∴ G 17 ( 6 18 # 3 19 1 1 20 + E 21 rcl 5 22 ∴ G 23 ▼ A 24 MEx 5 25 ) 6 26 ▼ A 27 goto 2 28 0 0 29 8 8 30 31 32 33 34	ln	4	13
) 6 16 ÷ G 17 ( 6 18 # 3 19 1 1 20 + E 21 rcl 5 22 ÷ G 23 ▼ A 24 MEx 5 25 ) 6 26 ▼ A 27 goto 2 28 0 0 29 8 8 30 31 32 33 34	÷		
÷ G 17 ( 6 18 # 3 19 1 1 20 + E 21 rcl 5 22 ÷ G 23 ▼ A 24 MEx 5 25 ) 6 26 ▼ A 27 goto 2 28 0 0 29 8 8 30 31 32 33 34	rcl	5	
( 6 18 # 3 19 1 1 20 + E 21 rcl 5 22 ÷ G 23 ▼ A 24 MEx 5 25 ) 6 26 ▼ A 27 goto 2 28 0 0 29 8 8 30 31 32 33 34		6	
# 3 19 1 1 20 + E 21 rcl 5 22 ÷ G 23 ▼ A 24 MEx 5 25 ) 6 26 ▼ A 27 goto 2 28 0 0 29 8 8 30 31 32 33 34			
1 1 20 + E 21 rcl 5 22 ÷ G 23 ▼ A 24 MEx 5 25 ) 6 26 ▼ A 27 goto 2 28 0 0 29 8 8 30 31 32 33 34			
+ E 21 rcl 5 22 ÷ G 23 ▼ A 24 MEx 5 25 ) 6 26 ▼ A 27 goto 2 28 0 0 29 8 8 30 31 32 33 34	#		
rcl 5 22	1		20
÷ G 23 ▼ A 24 MEx 5 25 ) 6 26 ▼ A 27 goto 2 28 0 0 29 8 8 30 31 32 33 34	+		21
▼ A 24  MEx 5 25  ) 6 26  ▼ A 27  goto 2 28  0 0 29  8 8 30  31  32  33  34		5	22
MEx 5 25 ) 6 26  ▼ A 27 goto 2 28 0 0 29 8 8 30 31 32 33 34		G	23
) 6 26 ▼ A 27 goto 2 28 0 0 29 8 8 30 31 32 33 34	•	Α	24
) 6 26 ▼ A 27 goto 2 28 0 0 29 8 8 30 31 32 33 34	MEx		25
goto 2 28 0 0 29 8 8 30 31 32 33 34	)	6	-
0 0 29 8 8 30 31 32 33 34	▼		
8 8 30 31 32 33 34		2	
31 32 33 34			
32 33 34	8	8	
33			
34			
The same of the sa		3	
35		134	
			35

## HARMONIC MEAN

$$\frac{1}{H} = \frac{1}{n} \left( \frac{1}{x_1} + \cdots + \frac{1}{x_n} \right)$$

Pre-execution:

G/CE / G/CE / ▲▼ / ▲▼ / goto / 0 / 0

Execution:

 $x_1 / RUN / x_2 / RUN / \cdots / x_n / RUN / \cdots$ 

harmonic mear

At each stage the harmonic mean so far is displayed.

÷	G	00
X		01
(	6	02
#	3	03
1	1	04
=	1	05
sto	2	06
)	6	07
+	Е	08
(	6	09
÷	G	10
=	==	11
stop	0	12
÷	G	13
÷	G	14
rcl	5	15
)	6	16
÷	G	17
(	6	18
#	3	19
1	1	20
+ rcl	Ε	21
rcl	5	22
÷	G	23
•	Α	24
MEx	5	25
)	6	26
•	Α	27
goto	2	28
0	0	29
8	8	.30
stop	0	31
VX	1	32
Stop .	0	33
rei		34
		35

## **ROOT MEAN SQUARE**

$$R = \frac{\sqrt{(x_1^2 + \dots + x_n^2)}}{n}$$

Pre-execution:

C/CE / C/CE / ▲▼ / ▲▼ / goto / 0 / 0

Execution:

 $x_1 / RUN / x_2 / \cdots / x_n / RUN /$ 

root-mean-square

At each stage the r.m.s. so far is displayed.

X		00
X		01
(	6	02
#	3	03
1	1	04
=	_	05
sto	2	06
)	6	07
+-	Е	80
(	6	09
$\sqrt{X}$	1	10
stop	0	11
X	1.	12
÷	G	13
rcl	5	14
)	6	15
v.* \ 3	G	16
(	6	17
#	3	18
1	1	19
+	Е	20
rcl	5	21
÷	G	22
•	Α	23
MEx	5	24
)	6	25
•	Α	26
goto	2	27
0	0	28
8	8	29
8 1	8	30
		31
		32
		33
		34
		35

## **QUADRATIC EQUATIONS**

$$ax^2 + bx + c = 0$$
  
Roots  $x_1, x_2$  if real  
R ± iI if complex

#### Execution:

a / RUN / b / RUN / c / RUN / x<sub>1</sub> / RUN / x<sub>2</sub> / RUN / RUN / <sup>C</sup>/CE / <sup>C</sup>/CE / if roots are real I\* / <sup>C</sup>/CE / RUN / R /

I\* / C/CE / RUN / R / if roots are complex

After the sequence a / RUN / b / RUN / c / RUN / the display shows either (if the roots are real) the larger real root with no error indication or (if the roots are complex) the imaginary part and the error symbol. Continue with the appropriate execution sequence.

The error symbol will tell you whether the roots are complex. The sequence / RUN / RUN /  $^{C}$ CE / shown above after  $(x_2)$  is necessary before entering a new equation to be solved.

+	Е	00
÷	G	01
-	F	02
X	•	03
sto	2	04
stop	0	05
= .	-	06
•	Α	07
MEx	5	80
X	5	09
stop	0	10
+	E	11
/o+uos	Е	12
(	6	13
rcl	5	14
X		15
)	6	16
any+ta	E	17
s1+\08 \\	Α	18
gin	1	19
3	3	20
2	2	21
2 √X	1	22
<b>V</b>	Α	23
MEx	5	24
s arit o	F	25
stop	F 0	26
rcl	5	26 27
- 0	F	28
rcl		29
zh <del>e</del> lion	5	30
stop	0	31
$\sqrt{X}$	1	32
stop	0	33
stop rcl	5	34
stop	0	35

<sup>\*</sup> error symbol displayed

## by an iterative method

$$ax^3 + bx^2 + cx + d = 0$$

Formula:

$$x_{k+1} = \frac{2ax_k^3 + bx_k^2 - d}{3ax_k^2 + 2bx_k + c}$$
 (based on Newton-Raphson method)

(Fill in your own values of 2a, b, d, etc.; if any of these are negative change the + or – preceding them to – or +)

#### Execution:

Choose any starting value  $x_o$ , say  $-\frac{d}{c}$ 

$$x_o / RUN / x_1 / RUN / x_2 / \cdots$$

If the sequence converges, the limit will solve the equation.

If the sequence does not converge, try a new starting value.

The sequence will usually converge to the root closest to the starting value and so by trying different starting values all the roots should be obtained.

\* where  $a_1 a_2$  is the two digit number 3a; if 3a < 10 then enter  $a_1 = 0$  and  $a_2$  as the value of 3a. Similarly  $b_1 b_2$  is 2b.

1	sto	2	00
	X		01
1	#	3	02
	а	а	03
	+	Е	04
	+	E	05
	#	3	06
	b	b	07
	X	Ŕ:	80
×	rcl	5	09
	X		10
1	rcl	5	11
	7	F	12
	#	3	13
	d	d	14
	/( <del>#</del> )\	G	15
	(	6	16
	#	3	17
	a <sub>1</sub>	a <sub>1</sub>	18
	a <sub>2</sub>	a <sub>2</sub>	19
	X		20
	rcl	5	21
15	erotor s	Ε	22
70	#	3	23
1	b <sub>1</sub>	$b_1$	24
	b <sub>2</sub>	$b_2$	25
	X	Dille	26
91	rcl	5	27
04	wtn s	Ε	28
	#	3	29
	С	С	30 31
	=	_	31
	)	6	32
	=	_	33
	stop	0	34
	= -	_	35

\*

### POLYNOMIALS

To evaluate

$$a_n x^n + a_{n-1} x^{n-1} + \cdots + a_0 = p(x)$$

Execution:

$$x / RUN / a_n / RUN / a_{n-1} / \cdots / a_1 / RUN / a_o /$$
  
= / result

To use again: (with different x)

▲▼ / ▲▼ / goto / 0 / 0 / before execution

#### Notes:

- 1. The individual results after each / RUN / are the coefficients of the polynomial q(x) where q(t) = p(t) / (t x).
- 2. If p(x) = 0, x is a root and q(x) is the quotient polynomial which can be solved for other roots of p(x).

sto	2	00
stop	0	01
X		02
rcl	5	03
+	Е	04
•	Α	05
goto	2	06
0	0	07
1	1	80
		09
	1 63	10
	sign	11
28 4 By	3 4	12
		13
	Def	14
	8251	15
		16
	itu	17
Total	AUS	18
		19
isos s		20
† 10 – † <i>si t</i> n		21
iiilum		22
xe 101	1970	23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

## POLYNOMIALS

To write a program to evaluate the same polynomial repeatedly

Example:

$$p(x) = 5x^4 + 8x^3 - 3x^2 + 4 \cdot 2x + 1$$

Method:

Express as 
$$[[(5x+8)x-3]x+4.2]x+1$$

Execution:

$$x / RUN / p(x) / y / RUN / p(y) \cdots etc.$$

Note: If a coefficient is zero omit it together with the — or + sign preceding it. If the leading coefficient is 1, it may be omitted together with the multiplication sign which precedes it. See over for example.

	_	
sto	2	00
X	•	01
#	3	02
5	5	03
+	E	04
#	3	05
8	8	06
X		07
rcl	5	80
rol	F	09
#	3	10
3	3	11
X		12
rcl	5	13
+	E	14
#	3	15
4	4	16
a) Willph	Α	17
2	2	18
X		19
rcl	5	20
+	E	21
#	3	22
1	1	23
=	_	24
stop	0	25
	Α	26
goto	2	27
0	0	28
0	0	29
0	0	30
		31
1		32
		33
stop	0	34
99 /		35

### **POLYNOMIALS**

first coefficient = 1, so omitted.

coefficient of x = 0, so omitted.

sto	2	00
+	Е	01
#	3	02
2	2	03
X		04
rcl	5	05
X	•	06
rcl	5	07
+	E	80
#	3	09
3	3	10
¥ S-n	12	11
stop	0	12
.○ ▼ ×	Α	13
goto	2	14
0	0	15
0	0	16
		17
		18
		19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34

#### Example:

To calculate  $x^3 + 2x^2 + 3$ 

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## DIVISION OF A POLYNOMIAL BY A QUADRATIC

Division of the polynomial  $p(x) = a_n x^n + a_{n-1} x^{n-1} + \cdots + a_1 x + a_0$  by the quadratic divisor  $d(x) = x^2 + mx + n$  gives the quotient polynomial  $q(x) = b_{n-2} x^{n-2} + b_{n-3} x^{n-3} + \cdots + b_1 x + b_0$  with remainder  $r(x) = c_1 x + c_0$ 

Pre-execution:

AV / AV / goto / 0 / 0 / C/CE / AV / sto /

#### Execution:

 $\begin{array}{l} RUN \, / \, n \, / \, RUN \, / \, m \, / \, RUN \, / \, a_n \, / \, RUN \, / \, b_{n-2} \\ RUN \, / \, n \, / \, RUN \, / \, m \, / \, RUN \, / \, a_{n-1} \, / \, RUN \, / \, b_{n-3} \\ RUN \, / \, n \, / \, RUN \, / \, m \, / \, RUN \, / \, a_2 \, / \, RUN \, / \, b_o \\ RUN \, / \, n \, / \, RUN \, / \, m \, / \, RUN \, / \, a_1 \, / \, RUN \, / \, c_1 \\ RUN \, / \, n \, / \, RUN \, / \, m \, / \, RUN \, / \, a_o \, / \, RUN \, / \, RU$ 

/RUN / RUN / completes execution

Results may be tabulated as below: e.g. to divide  $x^6 - 4x^5 + 31x^4 - 96x^3 + 415x^2 - 652x + 1105$  by  $x^2 + 2x + 3$ :

r	n	m	a <sub>r</sub>	$b_{r-2}$
6	3	2	1	1
5			-4	-6
4			31	40
3			-96	-158
2			415	611
1			-652	$-1400 = c_1$
0			1105	$-728 = c_{o}$

MEx 5 01  X · 02  stop 0 03  + E 04  ( 6 05  stop 0 06  X · 07	•	А	00
stop 0 03 + E 04 ( 6 05 stop 0 06 X · 07 rcl 5 08 ) 6 09 - F 10 stop 0 11 - F 12 = - 13 stop 0 14 ▼ A 15 goto 2 16 0 0 17 0 0 18 - 19 - 20 - 21 - 22 - 23 - 24 - 25 - 26 - 27 - 28 - 29 - 30 - 31 - 32 - 33 - 34	MEx		01
+ E 04 ( 6 05 stop 0 06 X	1		02
( 6 05 stop 0 06 X · 07 rcl 5 08 ) 6 09 - F 10 stop 0 11 - F 12 = - 13 stop 0 14 ▼ A 15 goto 2 16 0 0 17 0 0 18 19 . 20 21 22 23 24 25 26 27 28 29 30 31 31 32 33 34		0	03
stop 0 06  X 07  rcl 5 08  ) 6 09  - F 10  stop 0 11  - F 12  = - 13  stop 0 14  ▼ A 15  goto 2 16  0 0 17  0 0 18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34	+	E	04
X	(		05
rcl 5 08 ) 6 09 - F 10 stop 0 11 - F 12 = - 13 stop 0 14 ▼ A 15 goto 2 16 0 0 17 0 0 18 - 19 - 20 - 21 - 22 - 23 - 24 - 25 - 26 - 27 - 28 - 29 - 30 - 31 - 32 - 33 - 34	-		06
) 6 09 - F 10 stop 0 11 - F 12 = - 13 stop 0 14 ▼ A 15 goto 2 16 0 0 17 0 0 18 - 19 - 20 - 21 - 22 - 23 - 24 - 25 - 26 - 27 - 28 - 29 - 30 - 31 - 32 - 33 - 34			07
- F 10 stop 0 11 - F 12 = - 13 stop 0 14 ▼ A 15 goto 2 16 0 0 17 0 0 18 - 19 - 20 - 21 - 22 - 23 - 24 - 25 - 26 - 27 - 28 - 29 - 30 - 31 - 32 - 33 - 34			08
stop 0 11  - F 12  = - 13  stop 0 14  ▼ A 15  goto 2 16  0 0 17  0 0 18  - 19  - 20  - 21  - 22  - 23  - 24  - 25  - 26  - 27  - 28  - 29  - 30  - 31  - 32  - 33  - 34	)		1000
- F 12 = - 13 stop 0 14 ▼ A 15 goto 2 16 0 0 17 0 0 18 - 19 - 20 - 21 - 22 - 23 - 24 - 25 - 26 - 27 - 28 - 29 - 30 - 31 - 32 - 33 - 34	_		2.34
=	stop		
stop 0 14  ▼ A 15  goto 2 16  0 0 17  0 0 18  19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34	_	F	
▼ A 15 goto 2 16 0 0 17 0 0 18 19 . 20 21 22 23 24 24 25 26 27 28 29 30 31 32 33 34		-	
goto 2 16 0 0 17 0 0 18 19 . 20 21 22 23 24 25 26 27 28 29 30 31 32 33			
0 0 17 0 0 18 19 . 20 21 22 23 24 25 26 27 28 29 30 31 32 33			15
0 0 18 19 . 20 21 22 23 24 25 26 27 28 29 30 31 32 33	111/2		
19 . 20 . 21 . 22 . 23 . 24 . 25 . 26 . 27 . 28 . 29 . 30 . 31 . 32 . 33 . 34			
. 20 21 22 23 24 25 26 27 28 29 30 31 32 33	0	0	
21 22 23 24 25 26 27 28 29 30 31 32 33 34			19
22 23 24 25 26 27 28 29 30 31 32 33 34			20
23 24 25 26 27 28 29 30 31 31 32 33			21
24 25 26 27 28 29 30 31 32 33 34			
25 26 27 28 29 30 31 32 33 34			
26 27 28 29 30 31 32 33 34			
27 28 29 30 31 32 33 34	step		25
28 29 30 31 32 33 34	-		26
29 30 31 32 33 34	nesto	2	27
30 31 32 33 34	0		
31 32 33 34	100		
32 33 34			30
33 34			31
34			32
			33
35			34
			35

## SOLVING A POLYNOMIAL

This is an iterative method to find a quadratic factor of a polynomial. When the polynomial has been reduced to quadratic factors, these can be solved to give the real or complex roots of the original polynomial.

#### Stage 1:

Choose a starting quadratic divisor

$$d(x) = x^2 + mx + n \quad (say)$$

Divide p(x) by d(x) to give a quotient q(x) and remainder r(x) = rx + s

#### Stage 2:

Divide q(x) again by d(x) to give a new quotient q'(x) and remainder r'(x) = tx + u

#### Stage 3:

Find the coefficients m' and n' of the next iterate of the quadratic divisor using this program

#### Execution:

u / RUN / t / RUN / m / RUN / n / RUN / D p / RUN / t / RUN / u / RUN / s / RUN / r / RUN / t / RUN / — / + / n / = / n'

A▼ / A▼ /goto /2/5/r/RUN/u/RUN/ n/X/s/RUN/t/RUN/+/m/=/m'

$$D = u^2 + nt^2 - mut$$

$$m' = m + \frac{ru + nst}{D}$$

$$n' = n - \frac{rt + s(mt - u)}{D}$$

Re-enter the quadratic divisor program and iterate again with the new values of m' and n'. Repeat stages 1—3 until the values of m and n converge.

X		00
sto	2	01
_	F	02
(	6	03
rcl	5	04
X		05
stop	0	06
sto	2	07
X		08
stop	0	09
)	6	10
+	Е	11
(	6	12
rcl	5	13
X		14
X		15
stop	0	16
)	6	17
=	123	18
sto	2	19
stop	0	20
X	•	21
stop	0	22
	F	23
stop	0	24
X	•	25
stop	0	26
+	Е	27
(	6	28
stop	0	29
X	•	30
stop	0	31
)	6	32
÷	G	33
rcl	5	34
stop	0	35

## NUMERICAL INTEGRATION

Triangular interpolation

$$I = \frac{1}{2} h(y_o + 2y_1 + 2y_2 + \dots + 2y_{n-1} + y_n)$$

#### Execution:

 $n/RUN/y_o/RUN/y_1/RUN/y_2/RUN/\cdots$ / RUN/ $y_n/RUN/h/RUN/I$ 

_		F	:	0	(
#		3	3	0	1
1		1		0	2
=		_		0	3
sto		2		0	4
stop		0		0	5
+	b	E		0	6
(	7	6		0	
rcl		5		08	
entr <del>k</del> ię		F		0	9
#		3		10	)
1		1		11	
=		_		12	
sto		2		13	3
•		A		14	ŀ
gin	1	1		15	)
2		2		16	)
5		5		17	
stop	94	0		18	
+		E		19	
)		6		20	
<b>V</b>		Α		21	
goto		2		22	
0		0		23	
6		6		24	
stop		0		25	
)		6		26	
X				27	
stop		0		28	
÷		3		29	
#		3		30	
2	2	2		31	
=	-	-		32	
stop	(	)		3	
1 2 = 200	7	٠,		4	
= 4	_		3	5	

## NUMERICAL INTEGRATION

Simpson's Rule

$$I = \frac{1}{3}h(y_0 + 4y_1 + 2y_2 + 4y_3 + \dots + 4y_{n-1} + y_n)$$
(n must be even)

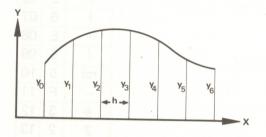
#### Execution:

 $n / - / 1 / = / RUN / y_1 / RUN / \cdots / y_n / RUN / h / RUN / I$ 

sto	2	00
stop	0	01
+	E	02
(	6	03
stop	0	04
+	Ε	05
+	Е	06
)	6	07
+	Е	08
(	6	09
rcl	5	10
R_X	F 3	11
#	3	12
2	2	13
=	_	14
sto	2 - 2	15
	Α	16
gin	1	17
2	2	18
7	2	19
stop	0	20
+	E	21
)	6	22
	6 A	23
goto	2	24
0	0	25
2	2	26
stop	0	27
)	6	28
X		29
stop	0	30
÷	G	31
#	3	32
stop ÷ # 3	3	33
=	_	34
stop	0	35

## NUMERICAL INTEGRATION

Weddle Formula



Integral = 
$$\frac{3h}{10}$$
 (y<sub>0</sub> + 5y<sub>1</sub> + y<sub>2</sub> + 6y<sub>3</sub> + y<sub>4</sub> + 5y<sub>5</sub> + y<sub>6</sub>)

#### Execution:

 $y_0$  / RUN /  $y_1$  / RUN /  $y_2$  / RUN /  $y_3$  / RUN /  $y_4$  / RUN /  $y_5$  / RUN /  $y_6$  / RUN /  $h_1$  / = / integral

	+		E		0	C
	' (		6	;	0	1
	stop		C	)	0	2
	X				0	3
	#		3		0	4
	5		5	,	0	5
	=		-	-	0	6
	)		6		0	7
	+		E		08	8
	stop		0		0	
	+		E		10	)
	(		6		11	
	stop		0		12	2
	X		•		13	3
	#		3		14	ŀ
	6		6		15	,
1	=		_		16	
	)		6		17	,
L	+		Е		18	
	stop		0		19	
	+		E	100	20	
L	(		6		21	
L	stop		0		22	
L	X		•	1	23	
L	#	L	3		24	
L	5	L	5		25	
L	=	ŀ	-		26	
L	)	_	6	$\overline{}$	27	
L	+		E		28	
L	stop		0	_	29	
L	X		•	-	30	
L	#		3		31	
			Α		32	
L	3		3		33	
	X	_	•		34	
	stop	(	0	3	35	

## **COMPLEX NUMBERS**

$$z = x + iy$$

To find magnitude and argument.

#### Execution:

If y = 0, then z = |x| and arg  $z = (0 \text{ if } x \ge 0, \pi \text{ if } x < 0)$ 

Otherwise, x / RUN / y / RUN / |z| / RUN / arg z

#### To find x and y given arg z and |z|

$$(-\pi \leqslant \arg z \leqslant \pi)$$

If arg z is 0, then x = |z| and y = 0If arg z is  $\pi$ , then x = -|z| and y = 0

Otherwise use polar-cartesian program, execution as follows:

|z| / RUN / arg z / RUN /  $\times$  / RUN /  $\gamma$ 

÷	G	00
(	6	01
X	• 0	02
*	G	03
stop	0	04
sto	2	05
+	Е	06
rcl	5	07
X	•	80
rcl	5 —	09
=	-0	10
$\sqrt{X}$	1	11
stop	0	12
)	6	13
+	Е	14
+ #	3	15
1	1	16
÷ #	G	17
#	3	18
2	2	19
=10	-	20
2 = √X	3 2 - 1 A	21
▼ arccos	Α	22
arccos	8	23
+	E	24
+ X	• 0	25
(	6	26
rcl	5	27
X		28
÷	G	29
$\sqrt{X}$	1	30
√x rcl	5	31
)	6	32
=	_	33
= stop	0	34
=	_	35
	-	

## DETERMINANTS

$$\begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix} = a_1 b_2 - a_2 b_1$$

#### Execution:

a<sub>1</sub> / RUN / b<sub>1</sub> / RUN / a<sub>2</sub> / RUN / b<sub>2</sub> / RUN / det

sto	2	00
stop	0	01
X		02
stop	0	03
_	F	04
(	6	05
rcl	5	06
X	:	07
stop	0	08
)	6	09
-	F	10
=	_	11
stop	0	12
. 🛦	Α	13
goto	2	14
0	0	15
0	0	16
		17
		18
		19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

## MATRIX MANIPULATION

#### 1. Matrix multiplication (steps 00-11)

$$AB = C$$

$$C_{ij} = \sum_{k=1}^{n} a_{ik} b_{kj}$$

#### Execution:

$$a_{i1}$$
 / RUN /  $b_{1j}$  / RUN /  $a_{i2}$  / RUN /  $b_{2j}$  / RUN / · · · ·  $a_{in}$  / RUN /  $b_{ni}$  / RUN /  $c_{ii}$ 

To restore zero total for next calculation, press <sup>C</sup>/<sub>CE</sub>.

#### Error correction:

For  $b_{kj}$ :  $\Delta \nabla / ) / C/CE / + / \Delta \nabla / ( / b_{kj})$ 

#### 2. Back substitution (steps 00-21)

(for AX = B where A is upper triangular)

$$x_{ij} = \frac{\left(b_{ij} - \sum_{k=i+1}^{n} a_{ik} x_{kj}\right)}{a_{ij}}$$

#### Pre-execution:

 $\Delta V / \Delta V / goto / 0 / 0 / for each x<sub>ij</sub>$ 

	_	
sto	2	00
(	6	01
stop	0	02
X	•	03
rcl	5	04
)	6	05
+	E	06
stop	0	07
rop V	Α	80
goto	2	09
0	0	10
0	0	11
#	3	12
0	0	13
_	F	14
stop	0	15
_	F	16
÷	G	17
stop	0	18
S = +	-	19
sto	2	20
stop	0	21
X		22
rcl	5	23
+	Е	24
stop	0	25
=	_	26
	Α	27
goto	2	28
2	2	29
1	1	30
	3.1	31
no man		32
		33
		34
		35

## MATRIX MANIPULATION

#### Execution:

 $x_{nj}$  / RUN /  $a_{in}$  / RUN / · · · /  $x_{i+1,j}$  / RUN /  $a_{i,i+1}$  / RUN /  $\sum a_{jk} x_{kj}$  $\Delta \forall$  /  $\Delta \forall$  / goto / 1 / 2 / RUN /  $b_{ij}$  / RUN /  $a_{ii}$  / RUN /  $x_{ij}$ 

#### Error correction:

For  $x_{kj}$ :  $C/CE / + / x_{kj}$ 

For  $a_{ik}$ :  $/ \blacktriangle \checkmark /) / C/CE / + / \blacktriangle \checkmark / (/ <math>a_{ik}$ 

For  $b_{ij}$ :  $C/CE / - / b_{ij}$ For  $a_{ii}$ :  $C/CE / \div / a_{ii}$ 

## 3. Adding a multiple of row i to row j in the augmented matrix (A/B) (steps 16-30)

$$a'_{jk} = a_{jk} + m_{ji}a_{ik},$$
  $b'_{jk} = b_{jk} + m_{ji}b_{ik}$ 

where  $m_{ji} = -\frac{a_{ji}}{a_{ii}}$ 

#### Pre-execution (each m<sub>ji</sub>):

▲▼ / ▲▼ / goto / 1 / 6 / C/CE

#### Execution:

 $a_{ji}$  / RUN /  $a_{ii}$  / RUN /  $m_{ji}$  error correction: re-run from 16  $a_{ik}$  / RUN /  $a_{jk}$  / RUN /  $a_{jk}$  for each k

 $b_{ik}$  / RUN /  $b_{jk}$  / RUN /  $b'_{jk}$  for each k

*Note:* If  $m_{ji}$  is known pre-execution can be and first part of execution  $m_{ji}$  / RUN /  $m_{ji}$ 

### **EQUATION SOLVING**

#### The secant method

In this variant of the Newton-Raphson method for solving the equation f(x) = 0, instead of computing the derivative f'(x) at each stage, an approximation to f'(x) at a point in the vicinity of a root  $x_r$  is used.

#### Stage 1: wole al sonagrevitoo il laupo era ser

Write a program segment to compute f(x) when x is in memory, taking up no more than 27 steps excluding the final / stop /. Enter the program starting at step 01, ending with the sequence / stop / ▼/ goto / 0 / 0 /.

Execution: x / RUN / f(x)

Evaluate f(x) for a range of values in which a root is likely to occur. If  $f(x_1)$  and  $f(x_2)$  have opposite signs, there is a root between  $x_1$  and  $x_2$ .

#### Stage 2:

Calculate an approximation to the derivative of f(x) as follows:

$$f(x_2) / - / f(x_1) / \div / \blacktriangle \blacktriangledown / (/x_1 / - /x_2 / \blacktriangle \blacktriangledown / ) / = / k - f'(x_r)$$

#### Stage 3:

The iteration formula for the secant method is

$$x' = x + \frac{f(x)}{K}$$

where K is a constant approximately equal to the derivative of f(x) at the root. K may be chosen to be equal to k, or may be an integer or a number with fewer digits than k, in which case it should be numerically larger than k.

*Note:* If the program segment in Stage 1 took 27 steps, there is room for only one digit for K in the following program. (contd. over)

sto	2	00
1.55	94.40	01
		02
PK/	1	03
r \ 95m	ups	04
1 . 5		05
2 21	oisi	06
		07
oug Tite		08
dt NO	988	09
ett Hen		10
1 26 09		11
9073		12
ਨਰ <u>ਜਦ੍ਹੀ</u> ਪ	/UIE	13
9		14
		15
		16
		17
		18
		19
		20
		21
		22
		23
		24
		25
		26
		27
(-) *÷	(F)	28
	G	29
#	3	30
K	K	31
+	E	32
rcl	5	33
=	_	34
stop	0	35

Starting at the final / stop / step, press / ▲▼ / LEARN / and enter the sequence:

 $/\div/\#/K/+/rcl/=/stop/$  for K positive, or  $/-/\div/\#/K/+/rcl/=/stop/$  for negative K

The sequence  $/ \nabla / goto / 0 / 0 / or / = / steps may be added at the end.$ 

Execution: x / RUN / x' / RUN / x'' · · ·

Repeat until successive values are equal. If convergence is slow, decrease K. If the results diverge, increase K.

If k is a small fraction, the /  $\div$  / step may be replaced by a /  $\times$  / step and K taken as the reciprocal of k.

See below for example.

#### Example:

To solve  $\cos x = x$ 

$$f(x) = \cos x - x$$

Take 
$$x_1 = \frac{\pi}{2}$$
,  $x_0 = 0$ .

Then 
$$\frac{f(x_0) - f(x_1)}{x_1 - x_0} = \frac{1 + \frac{\pi}{2}}{\frac{\pi}{2}} = 2$$

Program segment is / cos / - / rcl

Guess 1 as starting solution

#### Execution:

1/RUN/0.770223

/ RUN / 0.7440342

/ RUN / 0.7399375

/ RUN / 0.7392705 / RUN / 0.7391738

/ RUN / 0.7391592

/ RUN / 0.7391592 / RUN / 0.7391519

/ RUN / 0.7391483

/ RUN / 0.7391465

/ RUN / 0.7391456

/ RUN / 0·7391451

/ RUN / 0.7391449

/ RUN / 0.7391448

/ RUN / 0.7391447

/ RUN / 0.7391447

So result is 0.7391447

sto	2	00
cos	8	01
	F	02
rcl	5	03
÷	G	04
#	3	05
2	2	06
+	E	07
rcl	5	80
=	2	09
stop	0	10
•	Α	11
goto	2	12
0	0	13
0	0	14
		15
		16
	dfB:	17
AMUR	7.81	18
		19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
-		30
		31
		32
		33
		34
		35

## CIRCLES

Circumference and area

#### Execution:

radius / RUN / circumference / RUN / area

( 6 01	X		00
6 6 04  ∴ A 05 2 2 06 8 8 07 3 3 08 1 1 09 9 9 10 = - 11 stop 0 12 ) 6 13	(	6	01
6 6 04  ∴ A 05 2 2 06 8 8 07 3 3 08 1 1 09 9 9 10 = - 11 stop 0 12 ) 6 13	X		02
6 6 04  ∴ A 05 2 2 06 8 8 07 3 3 08 1 1 09 9 9 10 = - 11 stop 0 12 ) 6 13	#	3	03
2 2 06 8 8 07 3 3 08 1 1 09 9 9 10 = - 11 stop 0 12 ) 6 13 ÷ G 14 # 3 15 2 2 16 = - 17 stop 0 18 ▼ A 19 goto 2 20 0 0 21 0 0 22 0 0 0 21 0 0 22 23 24 24 25 26 27 28 29 30 31 31 32 33 34	6		04
8 8 07 3 3 08 1 1 09 9 9 10 = - 11 stop 0 12 ) 6 13 ÷ G 14 # 3 15 2 2 16 = - 17 stop 0 18 ▼ A 19 goto 2 20 0 0 21 0 0 22 0 23 23 24 25 26 27 28 29 30 31 32 33 34	5 V 2/3	Α	05
3 3 08 1 1 09 9 9 10 = - 11 stop 0 12 ) 6 13 ÷ G 14 # 3 15 2 2 16 = - 17 stop 0 18 ▼ A 19 goto 2 20 0 0 21 0 0 22 23 24 25 26 27 28 29 30 31 31 32 33 34	2	2	06
1 1 09 9 9 10 = - 11 stop 0 12 ) 6 13 ÷ G 14 # 3 15 2 2 16 = - 17 stop 0 18 ▼ A 19 goto 2 20 0 0 21 0 0 22 23 24 24 25 26 27 28 29 30 31 31 32 33 34			07
9 9 10 = - 11 stop 0 12 ) 6 13 ÷ G 14 # 3 15 2 2 16 = - 17 stop 0 18 ▼ A 19 goto 2 20 0 0 21 0 0 22 23 23 24 25 26 27 28 29 30 31 31 32 33 34			08
=		1	09
) 6 13  ÷ G 14  # 3 15 2 2 16  = - 17  stop 0 18  ▼ A 19  goto 2 20 0 0 21 0 0 22 23 23 24 25 26 27 28 29 30 31 32 33 34	9		10
) 6 13  ÷ G 14  # 3 15 2 2 16  = - 17  stop 0 18  ▼ A 19  goto 2 20 0 0 21 0 0 22 23 23 24 25 26 27 28 29 30 31 32 33 34	_ E.yx	_	
<ul> <li>÷ G 14</li> <li># 3 15</li> <li>2 2 16</li> <li>= - 17</li> <li>stop 0 18</li> <li>▼ A 19</li> <li>goto 2 20</li> <li>0 0 21</li> <li>0 0 22</li> <li>23</li> <li>24</li> <li>25</li> <li>26</li> <li>27</li> <li>28</li> <li>29</li> <li>30</li> <li>31</li> <li>32</li> <li>33</li> <li>34</li> </ul>		0	
# 3 15 2 2 16 = - 17 stop 0 18 ▼ A 19 goto 2 20 0 0 21 0 0 22 23 24 24 25 26 27 28 29 30 31 32 33 34		6	13
2 2 16 = - 17 stop 0 18 ▼ A 19 goto 2 20 0 0 21 0 0 22 23 24 25 26 27 28 29 30 31 32 33 34			14
2 2 16 = - 17 stop 0 18 ▼ A 19 goto 2 20 0 0 21 0 0 22 23 24 25 26 27 28 29 30 31 31 32 33 34		3	15
stop 0 18  ▼ A 19 goto 2 20 0 0 21 0 0 22 23 24 24 25 26 27 28 29 30 31 32 33 34		2	
▼ A 19 goto 2 20 0 0 21 0 0 22 23 24 25 26 27 28 29 30 31 32 33 34	=	_	17
goto 2 20 0 0 21 0 0 22 23 24 25 26 27 28 29 30 31 32 33			18
0 0 21 0 0 22 23 24 25 26 27 28 29 30 31 32 33 34	•		19
0 0 22 23 24 25 26 27 28 29 30 31 32 33 34	goto	2	20
23 24 25 26 27 28 29 30 31 32 33 34	0		21
24 25 26 27 28 29 30 31 32 33 34	0	0	22
24 25 26 27 28 29 30 31 32 33 34	ET JA		
25 26 27 28 29 30 31 32 33 34	ET (1)		24
27 28 29 30 31 32 33 34		108	25
28 29 30 31 32 33 34	21.0	101	26
29 30 31 32 33 34	2121	4110	27
29 30 31 32 33 34		1U3	28
30 31 32 33 34	Eroj.		
31 32 33 34	ET-0 \	108	30
32 33 34	1093	AUS	31
34	t is 0-70	1025	
34			
35			
			35

## **CIRCLES**

Radius of circle from area

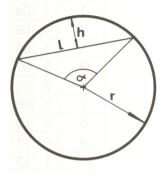
		0
-		A
1	1/	$\pi$

Execution:

÷	G	00
#	3	01
3	3	02
	Α	03
1	1	04
4	4	05
1	1	06
5	5	07
9	9	08
2	2	09
6	6	10
=	=/	11
$\sqrt{X}$	1	12
stop	0	13
•	Α	14
goto	2	15
0	0	16
0	0	17
		18
~/ 9		19
9-		20
S 50		21
Janear are		22
ot haris	nas	23
	7	24
ino		25
4 \ 11 \		26
		27
) banın	1 : 5	28
		29
		30
	-	31
		32
		33
		34
		35
		35

## CIRCLES

#### Area of segment:



Area of segment if h and r are given:

Area = 
$$\frac{r^2}{2}(\alpha - \sin \alpha)$$

where 
$$\cos \frac{\alpha}{2} = \frac{r - h}{r}$$

Note: the angle  $\alpha$  is calculated internally and is not required to be input.

#### Execution:

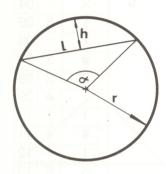
r/RUN/h/RUN/area

*Note:* limited range,  $\alpha$  < 1.57 radians

sto	2	00
_	F	01
stop	0	02
÷	G	03
rcl	5	04
=	-	05
•	Α	06
arccos	8	07
+	E	80
<b>-</b> .	F	09
(	6	10
sin	7	11
)	6	12
X		13
(	6	14
rcl	5	15
X	*	16
)	6	17
÷ 110	G	18
#	_	19
2	2	20
=	-	21
stop	0	22
•	Α	23
goto	2	24
0	0	25
0	0	26
		27
		28
		29
		30
		31
		32
		33
		34
		35

# CIRCLES

### Length of chord



$$I = 2\sqrt{2hr - h^2}$$

### Execution:

h/RUN/r/RUN/length

sto	2	00
X		01
(	6	02
stop	0	03
+	Е	04
_	F	05
rcl	5	06
)	6	07
+	E	08
$\sqrt{X}$	1	09
=	-	10
stop	0	11
•	Α	12
goto	2	13
0	0	14
0	0	15
		16
		17
		18
		19
		20
	NUP	21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

# CIRCLES

#### Area of circular annulus



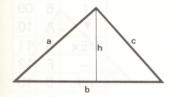
Area =  $\pi(R^2 - r^2)$ 

Execution:

R / RUN / r / RUN / area

		00
X		00
	F	01
(	6	02
stop	0	03
X		04
)	6	05
X		06
#	3	07
3	3	80
•	Α	09
1	1	10
4	4	11
1	1	12
5	5	13
9	9	14
=	-	15
stop	0	16
▼	Α	17
goto	2	18
0	0	19
0	0	20
		21
		22
	1	23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35
		00

To find area, given base and height



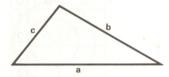
$$A = \frac{bh}{2}$$

Execution:

b/RUN/h/RUN/area

X		00
stop	0	01
÷	G	02
#	3	03
2	2	04
=	_	05
stop	0	06
•	Α	07
goto	2	80
0	0	09
0	0	10
		11
		12
		13
		14
		15
		16
		17
- 212		18
		19
		20
		21
		22
		23
		24
	19	25
		26
3030		27
4		28
	-	29
		30
		31
		32
		33
		34
		35

To find area, given all three sides



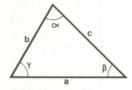
Area = 
$$\sqrt{s(s-a)(s-b)(s-c)}$$
  
where  $s = \left(\frac{a+b+c}{2}\right)$ 

### Execution:

a / RUN / b / RUN / c / RUN / b / RUN / a / RUN / area

+	Е	00
stop	0	01
+	E	02
stop	0	03
sto	2	04
÷	G	05
#	3	06
2	2	07
×		08
1	6	09
-		10
MEx	A 5 F 5	11
_	F	12
rcl	5	13
-	F	14
)	F 6	15
×		16
(	6	17
rcl	5	18
-	F	19
stop	0	20
)	6	21
X		22
(	6	23
rcl	5	24
_	F 0	25
stop	0	26
)	6	27
) = √x stop	_	28
$\sqrt{X}$	1	29
stop	0	30
•	Α	31
stop ▼ goto	2	32
0	0	33
0	0	34
		35

Finding a side, given two angles and a side



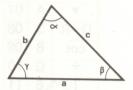
$$a = \frac{b \sin \alpha}{\sin \beta}$$

Execution:

 $\alpha^{\circ}$  / RUN /  $\beta^{\circ}$  / RUN / b / RUN / a

	Г	00
	F	
# .	3	01
9.	9	02
0	0	03
X	F.	04
=	-	05
$\sqrt{X}$	1	06
•	Α	07
D→R	3	08
cos	8	09
•	G	10
(	6	11
stop	0	12
-	F	13
#	3	14
9	9	15
0	0	16
X	i.	17.
_ =	_	18
√X	1	19
cos	8	20
)	6	21
X		22
stop	0	23
=	-	24
stop	0	25
<b>▼</b>	Α	26
goto	2	27
0	0	28
0	0	29
0		30
0		31
		32
		33
		34
		35
		00

Length of third side from two sides and included angle



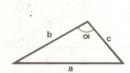
$$a = \sqrt{b^2 + c^2 - 2bc \cos \alpha}$$

Execution:

b/RUN/c/RUN/ $lpha^\circ$ /RUN/a

sto	2	00
stop	0	01
X		02
(	6	03
8 6	F	04
rcl	5	05
X		06
=	-	07
•	Α	80
MEx	5	09
+	E	10
)	6	11
X		12
(	6	13
stop	0	14
_	F	15
#	3	16
9	9	17
0	0	18
= 0	712	19
•	Α	20
D→R	3	21
sin	7	22
+	Е	23
#	3	24
1	1	25
=	-	26
)	6	27
+	Ε	28
rcl	5	29
= = =	-	30
$\sqrt{X}$	1	31
stop	0	32
=	_	33
=	-	34
=	_	35
	-	THE RESERVE OF THE PERSON NAMED IN

### Finding an angle, given three sides



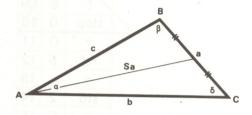
$$\cos \alpha = \frac{b^2 + c^2 - a^2}{2bc}$$

### Execution:

a/RUN/b/RUN/c/RUN/ $\alpha^{\circ}$ 

÷	G	00
stop	0	01
sto	2	02
Χ.	•	03
_	F	04
+	Е	05
#	3	06
1	1	07
X		08
(	6	09
stop	0	10
÷	G	11
rcl	5	12
=	-	13
sto	2	14
÷	G	15
)	6	16
+	E	17
rcl	5	18
+ ÷1)2	G	19
#	3	20
2	2	21
=	4116	22
=	Α	23
arcsin	7	24
•	7 A 6	25
R→D	6	26
_	F E	27
+	Е	28
+ #	3	29
9	9	30
0	0	31
= stop	_ 0	32
stop	0	33
= -	-	34
=	-	35

Length of medians, given lengths of sides



$$S_{a} = \frac{\sqrt{2(b^{2} + c^{2}) - a^{2}}}{2}$$

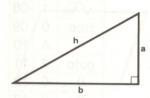
### Execution:

b/RUN/c/RUN/a/RUN/Sa

X		00
+	E	01
(	6	02
stop	0	03
X		04
)	6	05
+	Е	06
_	F	07
(	6	
stop	0	09
X		10
)	6	11
÷	G	12
#	3	13
4	4	14
=	_	15
$\sqrt{X}$	1	16
stop	0	17
-	Α	18
goto	2	19
0	0	20
0	0	21
	79	22
		23
	3	24
	1	25
1		26
	18	27
		28
TGL		29
		30
- VX	1	31
	0	32
- 12		33
		34
-		35

# RIGHT ANGLED TRIANGLES

Length of hypotenuse from other two sides



$$h = \sqrt{a^2 + b^2}$$

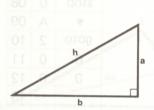
#### Execution:

a/RUN/b/RUN/h

X		00
+	E	01
(	6	02
stop	0	03
X		04
)	6	05
=	2	06
$\sqrt{X}$	1	07
stop	0	08
•	Α	09
goto	2	10
0	0	11
0	0	12
		13
	-	14
		15
		16
		17
Uno	31,0	18
1/8/1	18/	19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

# RIGHT ANGLED X . 00 TRIANGLES F 01 ( 6 02

Length of one short side from other two sides



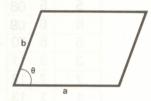
$$b = \sqrt{h^2 - a^2}$$

Execution:

a/RUN/h/RUN/b

- F 01 ( 6 02 stop 0 03 X 04 ) 6 05 - F 06 = - 07 √X 1 08 stop 0 09 ▲ A 10 goto 2 11 0 0 12 0 0 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 31 32 33 34	X		00
stop       0       03         X       ·       04         )       6       05         −       F       06         =       −       07         √X       1       08         stop       0       09         ▲       A       10         goto       2       11         0       0       12         0       0       13         16       17         18       19         20       21         22       23         24       25         26       27         28       29         30       31         32       33         34       34	1-1	F	01
X	(	6	02
) 6 05 - F 06 = - 07 √X 1 08 stop 0 09 ▲ A 10 goto 2 11 0 0 12 0 0 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34	stop	0	03
- F 06 = - 07 √X 1 08 stop 0 09 ▲ A 10 goto 2 11 0 0 12 0 0 13 14 15 16 17 18 19 20 21 22 23 24 24 25 26 27 28 29 30 31 32 33 34	X		04
=	)	6	05
√x 1 08 stop 0 09  ▲ A 10 goto 2 11 0 0 12 0 0 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34	+-	F	06
stop 0 09  A A 10 goto 2 11 0 0 12 0 0 13 14 15 16 17 18 19 20 21 22 23 24 24 25 26 27 28 29 30 31 32 33 34	=	-	07
A A 10 goto 2 11 0 0 12 0 0 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34	$\sqrt{X}$	1	08
goto 2 11 0 0 12 0 0 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34		0	
0 0 12 0 0 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33	•	Α	10
0 0 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33			
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33	0	0	12
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33	0	0	
16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33	4		14
17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33	-		
18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33	VXUT		
19 20 21 22 23 24 25 26 27 28 29 30 31 32 33	stop (		17
20 21 22 23 24 25 26 27 28 29 30 31 32 33	7 . 17		18
21 22 23 24 25 26 27 28 29 30 31 32 33	1946H V 3	HUT	19
22 23 24 25 26 27 28 29 30 31 32 33 34	.0		20
23 24 25 26 27 28 29 30 31 32 33 34	0		21
24 25 26 27 28 29 30 31 32 33 34			22
25 26 27 28 29 30 31 32 33 34			23
26 27 28 29 30 31 32 33 34			24
27 28 29 30 31 32 33 34			25
28 29 30 31 32 33 34			26
29 30 31 32 33 34			27
30 31 32 33 34			28
31 32 33 34			29
32 33 34			30
33 34			
34		13	32
			33
35		3	
		3	35

### PARALLELOGRAMS ?



Area =  $ab \sin \theta$ 

Execution:

a / RUN / b / RUN / θ° / RUN / area

For  $\theta$  in radians, insert /  $\nabla$  / R $\rightarrow$ D / between steps 04 and 05.

X	•	00
stop	0	01
X		02
(	6	03
stop	0	04
8-	F	05
#	3	06
9	9	07
0	0	80
=	_	09
•	Α	10
D→R	3	11
cos	8	12
)	6	13
=		14
stop	0	15
•	Α	16
goto	2	17
0	0	18
0	0	19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

# SPHERES

### Surface area and volume

$$A = 4\pi r^2$$

$$V = \frac{4}{3} \pi r^3$$

### Execution:

radius / RUN / surface area / RUN / volume

X		00
(	6	01
X	•	02
X		03
#	3	04
1	1	05
2	2	06
•	Α	07
5	5	08
6	6	09
6	6	10
3	3	11
7	7	12
1	1	13
=	_	14
stop	0	15
) de	6	16
*	G	17
#	3	18
3	3	19
anii Tean	: 13	20
stop	0	21
•	Α	22
goto	2	23
0	0	24
0	0	25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

# **SPHERES**

Radius from volume

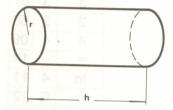
$$r = \sqrt{\frac{3V}{4\pi}}$$

Execution:

V/RUN/r

X		00
#	3	01
	Α	02
2	2	03
3	3	04
8	8	05
7	7	06
3	3	07
2	2	08
	4	09
4 =	1	10
In	4	11
÷	G	12
#	3	13
3	3	14
=	-	15
-	Α	16
e <sup>x</sup>	4	17
stop	0	18
	Α	19
goto	2	20
0	0	21
0	0	22
Bearing II	100	23
	g.	24
		25
	7	26
	. 8	27
	3	28
10	9	29
	n.	30
		31
		32
		33
		34
		35

### **CYLINDERS**



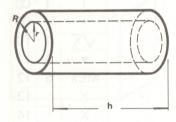
Volume =  $\pi r^2 h$ Area of curved surface =  $2\pi r h$ Total surface area =  $2\pi r (r + h)$ 

### Execution:

r / RUN / h / RUN / volume / RUN / area of curved surface / RUN / total surface area

	sto		2		00
	X				01
	X				02
	#		3		03
	6		6		04
			Α		05
	2		2		06
	8		8		07
	3		3		08
	1		1		09
	8	1	8		10
	5	1	5		11
	3	T	3		12
	+	T	E		13
	(	Ī	6		14
	÷		G	1	15
	#	3	3	8	16
	2	T	2	Ī	17
	X			1	18
	stop	1	0	I	19
	÷	I	G	1	20
	stop	I	0		21
	rcl	Γ	5	1	22
	+	Ī	E	1	23
	)		6	1	24
	stop		0	1	25
L	=	-	_		26
L	stop	-	0	2	27
L	•	1	4		28
	goto	:	2		29
	0		0		30
L	0	(	)	3	31
				3	32
L				3	3
L				3	4
				3	5
					-

### HOLLOW CYLINDRICAL TUBE



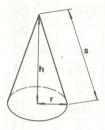
Area of curved surface =  $2\pi h(R + r)$ Volume =  $\pi h(R^2 - r^2)$ 

#### Execution:

R / RUN / r / RUN / h / RUN / area of curved surface / RUN / volume

+	E	00
stop	0	01
stop	2	02
÷	G	03
#	3	04
2	2	05
_	F	06
~	Α	07
MEx	5	08
=	7	09
*	Α	10
MEx	5	11
X		12
stop	0	13
X		14
#	3	15
1	1	16
2	2	17
	A	18
5	5	19
6	6	20
	6	21
X		22
stop	0	23
rcl	-	24
=\	Zrr	25
stop	0	26
<b>▼</b>	A	27
goto	2	28
0	0	29
0	0	30
-		31
		32
		33
		34
		35
		00

# RIGHT CIRCULAR CONE



Volume = 
$$\frac{\pi r^2 h}{3}$$

Curved surface area =  $\pi r \sqrt{r^2 + h^2}$ Total surface area =  $\pi r \left(r + \sqrt{r^2 + h^2}\right)$ 

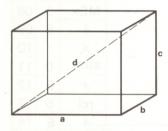
### Execution:

h / RUN / r / RUN / area of curved surface /

AV / rcl / area of base / RUN / total surface
area / RUN / volume

	_					
	X					00
	(		6		01	
	÷		G		02	
	stop		(			3
	sto		2		0	
	X				0	5
	+		E		0	
	#		3		07	
	1		1		0	
	=		-	1	0	9
	$\sqrt{X}$		1		10	0
			A		1	1
	MEx		5		1:	2
	X				13	3
	X		•		14	1
	#		3		15	5
	3		3		16	3
		T	Α		17	7
	1		1	T	18	3
53	4		4		19	)
SIS	1	9	1		20	)
	6	I	6	T	21	١
	X	1			22	
	•	1	A		23	
	MEx		5		24	
	+		E		25	
	stop		0	1	26	
	=		_		27	
	stop		0		28	
	rcl		5		29	
	)		6		30	
	÷	(	G		31	
	#	,	3		32	
	3	,	3		33	
	=		_		34	
	stop	(	)	3	35	

# RECTANGULAR PARALLELEPIPED



Diagonal:

$$d = \sqrt{a^2 + b^2 + c^2}$$

Execution:

a/RUN/b/RUN/c/RUN/d

X	•	00
+	E	01
(	6	02
stop	0	03
X	•	04
)	6	05
+	Е	06
(	6	07
stop	0	80
X	·	09
)	6	10
=	-	11
$\sqrt{X}$	1	12
stop	0	13
	Α	14
goto	2	15
0	0	16
0	0	17
		18
		19
		20
		21
		22
		23
		24
		25
		26
		27
		28
		29
		30
		31
		32
		33
		34
		35

# RECTANGULAR PARALLELEPIPED

Surface area

A = 2(ab + ac + bc)

Execution:

a / RUN / b / RUN / c / RUN / area

sto	2	00
stop	0	01
+	E	02
(	6	03
X	•	04
rcl	5	05
=	-	06
•	Α	07
MEx	5	80
)	6	09
X		10
stop	0	11
+	E	12
rcl	5	13
+	Е	14
=	_	15
stop	0	16
•	Α	17
goto	2	18
0	0	19
0	0	20
		21
	17.37	22
A Ld /	M.J.	23
		24
1716		25
		26
	1	27
		28
	1	29
		30
	1	31
		32
		33
-		34
		35

# TWO POINTS IN SPACE

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2}$$
points are  $(x_1, y_1, z_1)$  and  $(x_2, y_2, z_2)$ 

### Execution:

 $x_1 / RUN / x_2 / RUN / y_1 / RUN / y_2 / RUN / 0 = y base$  $z_1 / RUN / z_2 / RUN / d$ 

_	F	00
stop	0	01
X	•	02
+	Е	03
(	6	04
stop	0	05
_	F	06
stop	0	07
X		08
)	6	09
+	Е	10
(	6	11
stop	0	12
+	F	13
stop	0	14
X		15
) (00	6	16
A =0 \	(A)	17
$\sqrt{X}$	1	18
stop	0	19
	Α	20
goto	2	21
0	0	22
0	0	23
		24
		25
		26
		27
		28
		29
		30
		31
		32
	arrive.	33
4000	0	34
	in the second	35

# 

Polar to cartesian

 $\theta$  in radians,  $-\pi < \theta < \pi$ ,  $\theta \neq 0$ 

#### Execution:

 $r/RUN/\theta/RUN/x/RUN/y$ 

If  $\theta = 0$ , x = r and y = 0

If  $\theta = \pi$ , x = -r and y = 0

X		00
(	6	01
stop	0	02
÷	G	03
#	3	04
2	2	05
=	-	06
tan	9	07
sto	2	08
*	G	09
+	E	10
rcl	5	11
÷	G	12
+	E	13
)	6	14
=	_	15
•	Α	16
MEx	5	17
9 <u>07</u> 0.	F	18
(	6	19
) ÷	G	20
)	6	21
*	G	22
#	3	23
2	2	24
	F	25
X		26
rcl	5	27
=	_	28
stop	0	29
rcl	5	30
stop	0	31
=	_	32
=	_	33
=	_	34
=	_	35

# COORDINATE

Cartesian to polar

Restriction:  $y \neq 0$ 

If 
$$y = 0$$
,  $r = |x|$ 

and 
$$\theta = 0$$
 if  $x \ge 0$ 

 $\pi$  if x < 0

Execution:

x/RUN/y/RUN/r/RUN/0

÷	G	00
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rcl	5	07
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=	_	10
$\sqrt{X}$	1	11
stop	0	12
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rcl	5	27
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$\sqrt{X}$	1	30
rcl	5	31
)	6	32
= stop	_	33
	0	34
=	_	35

# RADIUS OF CURVATURE

$$r = \frac{\left[1 + \left(\frac{dy}{dx}\right)^2\right]^{\frac{3}{2}}}{\frac{d^2y}{dx^2}}$$

### Execution:

$$/\frac{dy}{dx}$$
 / RUN  $/\frac{d^2y}{dx^2}$  / RUN / r

X		00
+	E	01
#	3	02
1	1	03
X	•	04
(	6	05
$\sqrt{X}$	1	06
)	6	07
• •	G	80
stop	0	09
=	=	10
stop	0	11
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goto	2	13
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# HAVERSINE AND INVERSE HAVERSINE, VERSINE AND SUVERSINE

Haversine:

pre-execution: AV / goto / 0 / 0 /

Execution:

 $\theta^{\circ}$  / RUN / hav  $\theta$ 

 $/ + / = / \text{ vers } \theta / - / + / 2 / = / \text{ suvers } \theta$ 

Inverse haversine:

pre-execution: AV / goto / 1 / 4 /

Execution:

hav  $\theta$  / RUN /  $\theta^{\circ}$ 

vers  $\theta$  / ÷ / 2 / = / RUN /  $\theta$ °

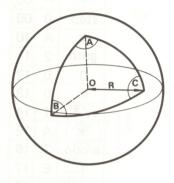
suvers  $\theta / - / + / 2 / \div / 2 / = / RUN / \theta^{\circ}$ 

Range  $0 \le \theta^{\circ} \le 180$ 

For vers  $\theta$  see post and pre-execution.

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D→R	3	01
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arcsin	7	16
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•	Α	19
R→D	6	20
stop	0	21
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goto	2	23
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# AREA OF A SPHERICAL TRIANGLE



Area =  $(A + B + C - \pi)R^2$ 

A, B, C in degrees

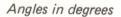
Execution:

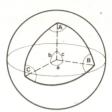
A / RUN / B / RUN / C / RUN / R / RUN / area

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	+	E	02
	stop	0	03
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	stop	0	14
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	)	6	16
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	stop	0	18
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# SPHERICAL TRIANGLES: SINE RULE

$$\frac{\sin A}{\sin a} = \frac{\sin B}{\sin b} = \frac{\sin C}{\sin c}$$





#### Execution:

a / RUN / A / RUN / B / RUN / b / C / RUN / c

or

A / RUN / a / RUN / b / RUN / B / c / RUN / C

Note: If a result of 0 appears, the final arcsin had an out-of-range argument and the result is impossible for the particular angles given, or else very close to 90°.

For angle A > 90°, compute using 180 / - / A / = / etc.

### Special execution: navigation

To find course from place 2 to place 1

$$\sin C = \frac{\sin (E_1 - E_2) \cos N_2}{\sin d}$$

#### Execution:

 $E_1/-/E_2/RUN/d/RUN/90/-/N_2/=/RUN/C$ 

where  $E_1$  = easterly longitude of place 1

E<sub>2</sub> = easterly longitude of place 2

 $N_2$  = north latitude of place 2

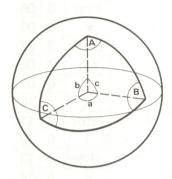
d = angular distance between places 1 and 2

(For westerly longitudes or south latitudes, change sign of angle.)

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sin 7 02 ÷ G 03 ( 6 04 stop 0 05 ▼ A 06 D→R 3 07 sin 7 08 ) 6 09 X · 10 sto 2 11
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# SPHERICAL TRIANGLES:

Cosine Rule



 $\cos a = \cos b (\cos c + \sin c \tan b \cos A)$ 

#### Execution:

c/RUN/A/RUN/b/RUN/b/RUN/a

### Navigation

To find great circle distance between places 1 and 2

- 1. Latitude  $N_1$  longitude  $E_1$  (-ve if W)
- 2. Latitude N<sub>2</sub> longitude E<sub>2</sub> (--ve if W)

### Execution:

 $90 / - / N_2 / = / RUN / E_1 / - / E_2 / RUN / 90 / - / N_1 / RUN / 90 / - / N_1 / RUN / d (degrees)$ 

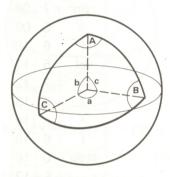
 $\times$  / 111·19 / = / distance in km or  $\times$  / 69·41 / = / distance in miles

For angles greater than  $90^{\circ}$  use appropriate reductions to first quadrant.

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D→R	3	01
sto	2	02
sin	7	03
X		04
(	6	05
stop	0	06
•	Α	07
D→R	3	80
COS	8	09
)	6	10
X		11
(	6	12
stop	0	13
•	Α	14
D→R	3	15
tan	9	16
) )	6	17
+	Ε	18
(	6	19
rcl	5	20
cos	8	21
)	6	22
X	•	23
(	6	24
stop	0	25
▼ 100	Α	26
D→R	3	27
cos	8	28
)	6	29
91220 5	=	30 31
arccos	Α	31
arccos	8	32
<b>V</b>	Α	33
R→D	6	34
stop	0	35

### SPHERICAL TRIANGLES

The Cosine Rule — to find an angle or side given three sides or angles



$$\cos A = \frac{\cos a - \cos b \cos c}{\sin b \sin c}$$

$$\cos a = \frac{\cos A + \cos B \cos C}{\sin B \sin C}$$

#### Execution:

Angles in radians

c/RUN/b/RUN/-/RUN/a/RUN/A C/RUN/B/RUN/RUN/A/RUN/a

For angles in degrees use

A▼ / A▼ / D→R / after each angle.

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sto	2	00
sin	7	01
•	Ą	02
MEx	5	03
cos	8	04
X		05
(	6	06
stop	0	07
sin	7	80
X	7.0	09
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MEx	5	11
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MEx	5	14
X	. 5	15
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stop	0	21
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(	6	23
stop	0	24
cos	8	25
)	6	26
•	G	27
rcl	5	28
=	_	29
•	Α	30
arccos	8	31
stop	0	32
=	-	33
=	_	34
=	-	35

# SPHERICAL TRIANGLES:

Half-angle tangent formula

$$\tan \frac{A}{2} = \sqrt{\frac{\sin (s - b) \sin (s - c)}{\sin (s - a) \sin s}}$$

where 
$$s = \frac{a+b+c}{2}$$

$$\tan \frac{a}{2} = \sqrt{\frac{\cos (\pi - S) \cos (S - A)}{\cos (S - B) \cos (S - C)}}$$

where 
$$S = \frac{A + B + C}{2}$$

#### Execution:

Angles in radians

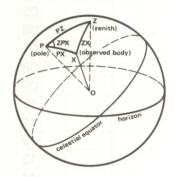
$$\frac{A}{2}/=/A$$

For the cosine version change all / sin / steps to / cos /.

sto	2	00
÷	G	01
#	3	02
2	2	03
_		04
•	F	05
MEx	5	06
=	-	07
sin	7	80
÷	G	09
(	6	10
rcl	5 7	11
sin	7	12
)	6	13
X		14
(	6	15
stop	0	16
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=	-	19
sin	7	20
)	6	21
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stop	0	24
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rcl	5	26
=	_	27
sin	7	28
) 29	6	29
= \(\sqrt{X}\)	_	30
√X	1	31
<b>V</b>	Α	32
arctan	9	33
arctan +	E	34
stop	0	35

# SPHERICAL TRIANGLES

### Solving the PZX triangle



hav ZX = hav (PX  $\sim$  PZ) + sin PX sin PZ hav  $\angle$ ZPX = hav (L  $\sim$  D) + cos L cos D hav  $\angle$ ZPX

(for the second formula use cos at steps 10 and 27 instead of sin)

ZX is the calculated zenith distance (CZD)

Enter south latitudes as -ve

Execution:

Angles in radians -

ZPX / RUN / PX / RUN / PZ / RUN / + / = / ZX

Angles in degrees -

 $\angle ZPX^{\circ}$  /  $\triangle \blacktriangledown$  /  $D \rightarrow R$  / RUN /  $PX^{\circ}$  /  $\triangle \blacktriangledown$  /  $D \rightarrow R$  / RUN /  $PZ^{\circ}$  /  $\triangle \blacktriangledown$  /  $A \blacktriangledown$  /  $D \rightarrow R$  / RUN / + / = /  $\triangle \blacktriangledown$  /  $A \blacktriangledown$  /  $R \rightarrow D$  /  $ZX^{\circ}$ 

Intercept I = CZD - TZD (calculated - true zenith distance)

Post-execution:

/-/TZD/X/60/=/I'(I in minutes of arc or miles approx.)

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=	-	03
sin	7	04
X		05
X		06
(	6	07
stop	0	08
sto	2	09
sin	7	10
)	6	11
X		12
(	6	13
stop	0	14
-	F	15
•	F	16
MEx	5	17
÷	G	18
#	3	19
2 =	2 - 7	20
=	_	21
sin	7	22
X		23
=	_	24
	– А 5	25
MEx	5	26
sin	7	27
)	6	28
+	Е	29
rcl	7 6 E 5	30
=	_	31
$\sqrt{X}$	1	32
= √X ▼	Α	33
arcsin	7	34
stop	0	35

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